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SOME LATER CENOZOIC FORAMINIFERA FROM CAPE BLANCO, OREGON

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ABSTRACT—The lithology and significant fossils of the Cenozoic formations exposed at Cape Blanco, Oregon, are discussed briefly. Twenty-four species of Foraminifera are described, figured, and analyzed; four new species and two new varieties are reported. Information is introduced which raises a question as to the correlation of the terrace beds at the cape with the Elk River beds just north of Elk River.

INTRODUCTION

In 1941 the writer made a study of the larger invertebrate fossils of the Cenozoic strata which are exposed along the Oregon coastal area in the vicinity of Cape Blanco (Bandy, 1941). At that time Foraminifera were found in the middle Eocene and the study of those forms was published in 1944 (Bandy, 1944). Some smaller Foraminifera were also found in the Pliocene and Pleistocene strata and the present report is primarily concerned with an analysis and study of these forms and their stratigraphic implications. The types are catalogued and deposited in the paleontological collection, University of Southern California.

A recent report on the late Cenozoic stratigraphy of the southern Oregon coastal area (Baldwin, 1945) brings together most of the pertinent stratigraphic data for the Cape Blanco area and a new formation, the Port Orford formation, was proposed for the middle Pliocene beds exposed south of the cape.

STRATIGRAPHIC AND FAUNAL CONSIDERATIONS

The formations exposed in this area are tabulated below (Table 1), and the generalized stratigraphic relations may be seen in figure 2. Following the tabulation is a brief discussion of the significant faunal elements of each formation.

TABLE 1—GEOLOGIC FORMATIONS, CAPE BLANCO, OREGON

PLEISTOCENE—Elk River formation	
Rotalia tenerrima zone—unconformity —(?)	± 10′
Elphidiella zone—unconformity—	± 90′
PLIOCENE—Port Orford formation—unconformity—	±150′
Empire formation fault contact	±420′
MIDDLE EOCENE—*Amphistegina simiensis* zone base unexposed	

Middle Eocene

Strata of this age are exposed on the south side of Cape Blanco (figures 1, 2; locality

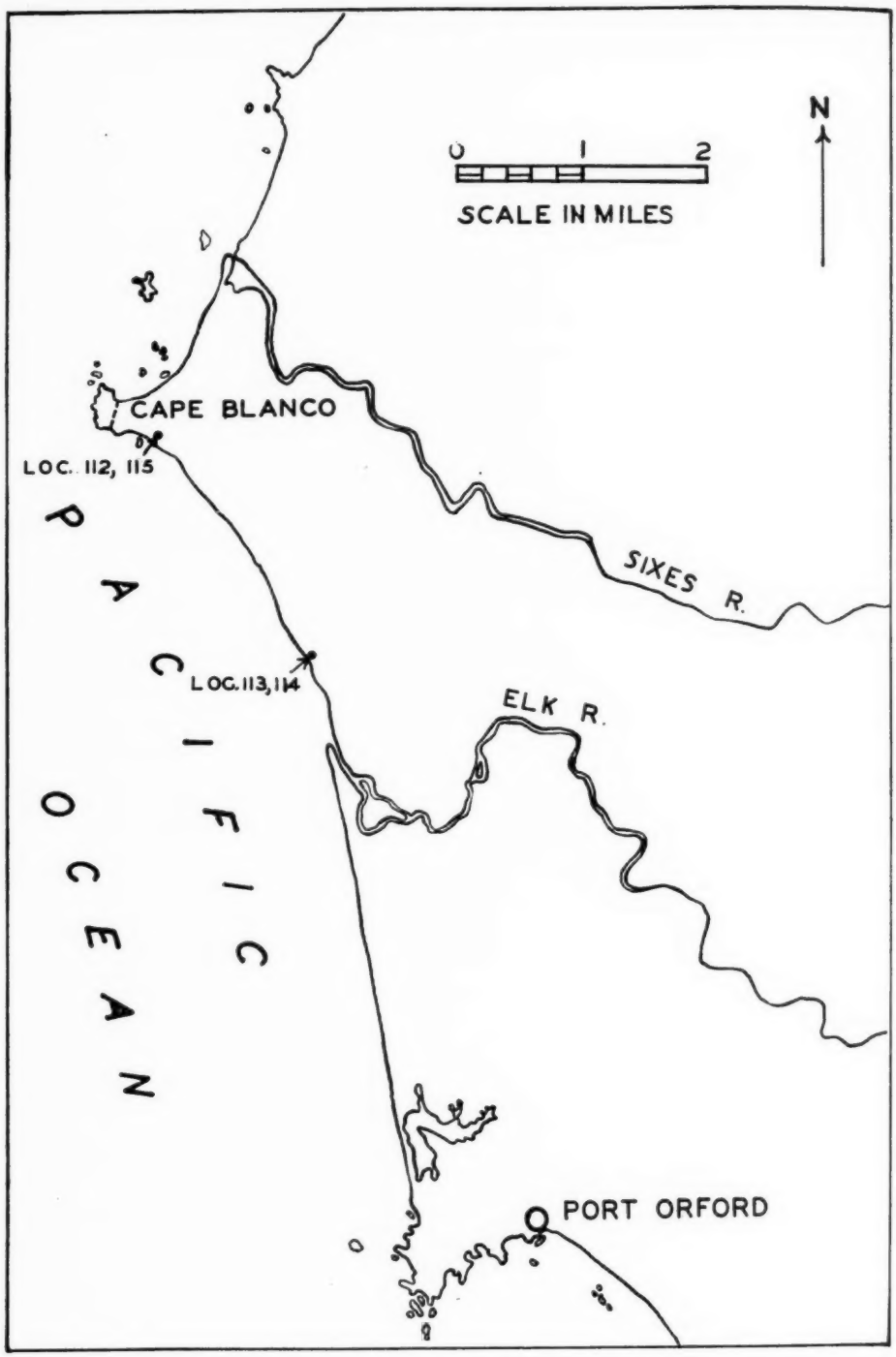


FIG. 1—Outline map of Cape Blanco, Curry County, Oregon.

112). These sediments are highly indurated and deformed grayish silts and shales, the former with an abundance of characteristic Eocene Foraminifera (Bandy, 1944). The diagnostic and common Foraminifera are: *Amphistegina simiensis* (Cushman and McMasters), *Anomalina packardi* Bandy, *Lamarckina rugatina* Bandy, and *Rotorbinella colliculus* Bandy.

Lower Pliocene

Empire formation.—This formation forms the main portion of the sea cliffs from just south of Cape Blanco southward for about one and one-half miles. The outer portion of the Cape is also made of these sediments. The dip varies from 8–14° to the south and the beds are about 420′ in thickness. Farther south the Port Orford formation appears, overlying the Empire formation with an angular discordance. The sediments of the Empire are mostly yellowish sandstones with some tuffaceous members and are characterized by a megafauna only. The more characteristic forms are *Mytilus middendorffi* Grewingk and *Venus securis* Shumard.

Middle or Upper Pliocene

Port Orford formation.—This formation is composed of a basal buff sand overlain by conglomerate followed in turn by a rusty sand which grades upward into a 75′ bed of blue-gray argillaceous sand and shale bearing fossiliferous concretions. The beds of this formation lie unconformably between the Empire and the overlying deposits of the Elk River formation exposed about two miles south of the lighthouse at Cape Blanco (figures 1, 2; locality 113). The dip of these beds is from 3°–4° to the south. Most of the concretions of the blue-gray argillaceous sand bed contain specimens of *Clementia subdiaphana* Carpenter. This zone yielded the following species of Foraminifera which are listed according to their relative abundance, considering the entire Foraminiferal fauna as constituting one hundred per cent.

Elphidiella hannai	60%
Nonionella basispinata	15
Eponides frigidus	5
Eponides blancoensis	3
Gaudryina arenaria	3
Nonionella miocenica	3
Textularia abbreviata	3
Polymorphina oregonensis	2
Buliminella elegantissima	1
Cibicides lobatus	1
Marginulina glabra	1
Robertina californica	1
unidentified fragments	2

The above fauna correlates rather well with the Pliocene Foraminifera of Humboldt County, California (Cushman, Stewart and Stewart, 1930). A very shallow cool environment of deposition is indicated by reported existing ranges of the seven most abundant species occurring in the fauna. These are as follows: *Elphidiella hannai* (Cushman and Grant) has a continuous range from Alaska to Mexico in very shallow water (Cushman and McCulloch, 1940); *Nonionella basispinata* (Cushman and Moyer) is reported in shallow water from Alaska to Ecuador (Cushman and McCulloch, 1940); *Eponides frigidus* (Cushman) is reported in the coastal waters of Washington (Cushman and Todd, 1947); *Gaudryina arenaria* (Galloway and Wissler) is reported widely distributed along the eastern shore of the Pacific in 8 to about 50 fathoms of water; *Nonionella miocenica* (Cushman) is known from Wrangell, Alaska, in two fathoms, to Port Culebra, Costa Rica, in three–ten fathoms (Cushman and McCulloch, 1940).

Pleistocene

Elk River formation.—The strata of this formation include a ten-foot bed of terrace sands and gravels to the north of and just south of the cape (figure 2, locality 114) and about 90 feet of gently southward-dipping gray sands just north of the mouth of Elk River (figure 2, locality 115) (Baldwin, 1945). Baldwin follows the suggestion of Martin (1916) that these two non-contiguous beds are correlative. The writer (Bandy, 1941) has identified the faunas of the two beds and there is little by way of correlation between the two; hence, they are treated separately. The section just north of the mouth of Elk River is characterized by extremely abundant specimens of *Psephidea lordi* (Baird) and *Elphidiella hannai* (Cushman and Grant) and is designated as the *Elphidiella* zone in the discussion below. The ten-foot bed of terrace gravels at Cape Blanco is characterized by

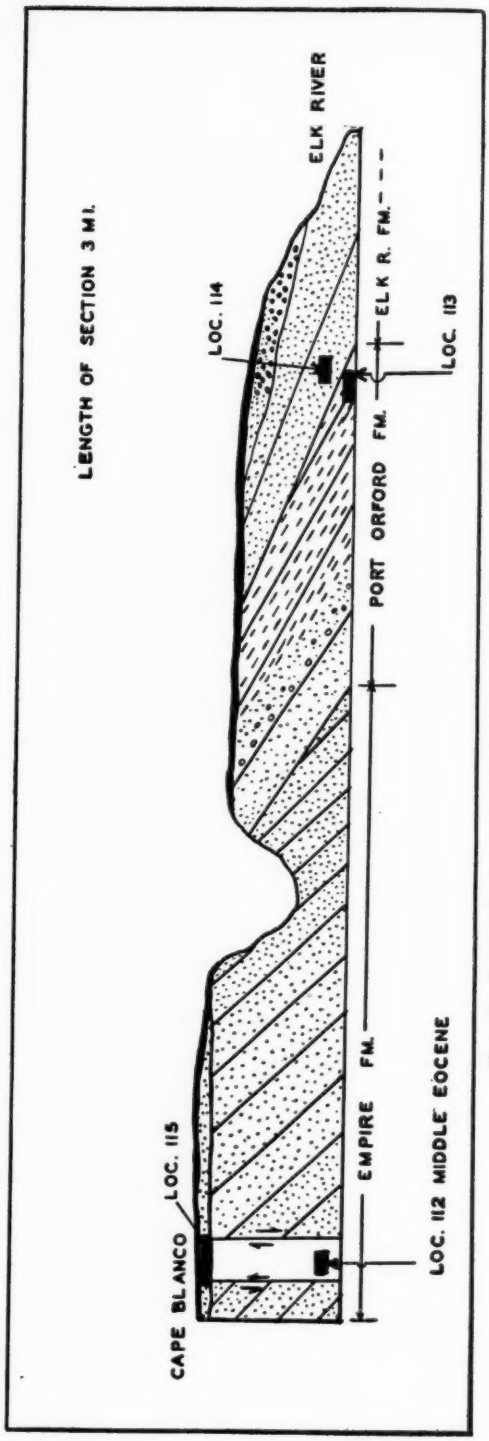


FIG. 2—Generalized section of bluffs from Cape Blanco to Elk River.

an abundant pelecypod fauna near the base with *Schizothaerus nuttalli* (Conrad) and *Saxidomus nuttalli* (Conrad) being the most characteristic members. This last zone is designated as the *Rotalia tenerrima* zone in the following discussion:

Elphidiella zone. The Foraminifera of this zone are listed below in order of abundance.

Elphidiella hannai	86%
Elphidiella oregonensis	5
Elphidium hughesi	2
Eponides blancoensis	2
Nonion basispinatus	2
Quinqueloculina akneriana var. *bellatula*	2
Cassidulina limbata	rare
Cibicides lobatus	rare
Elphidium granulosum	rare
Globigerina bulloides	rare

It is significant that this fauna falls into Natland's Zone II (Natland, 1933) which has a bottom temperature range of 21.43°C. –13.20°C. and a depth range of 14–125 feet. Cushman and McCulloch (1940), as indicated earlier, report *Elphidiella hannai* as having a continuous range off the coast from Cordova, Alaska, southward to the east side of Cedros Island, Mexico, in shallow waters. Cushman and Todd (1947) also report this form in the shallow coastal waters of Washington.

Rotalia tenerrima zone. Following is the percentage-abundance list of Foraminifera found in the basal fossiliferous horizon of the thin terrace deposits just south of Cape Blanco.

Rotalia tenerrima	18%
Discorbis ornatissimus oregonensis	15
Elphidium granulosum	13
Cibicides lobatus	10
Elphidiella hannai, weathered and reworked	10
Rotalia subcorpulenta	10
Cassidulina limbata	5
Fissurina lucida	rare
Globigerina bulloides	rare
Quinqueloculina akneriana bellatula	rare
Uvigerina bradyana	rare

Here again, the indicated habitat is one of shallow water to strand-line type of deposition. The distinction between this and the fauna of the *Elphidiella* zone is marked. Nearly all of the specimens of *Elphidiella hannai* found in this zone are quite eroded and weathered in appearance, indicating that they are probably derived and not a

natural component of the biota. The other faunal elements are well preserved.

Bruce Martin (1916) noted a difference between the fauna of the terrace deposits at Cape Blanco and the fauna of the Elk River deposits just north of the mouth of Elk River, but he concluded that this might be caused by the difference in position with regard to the strand-line. After examining the megafossils (Bandy, 1941) and the microfossils, it appears that there may be a possible unconformable contact between the two zones encompassed in the Elk River formation at Cape Blanco. The evidence for such conclusion is fourfold and may be summarized as follows: (1) The megafossils of the two zones comprise two almost entirely separate faunas; (2) the microfossil faunas (Foraminifera) are entirely distinct, the only significant exception being in the presence of *Elphidiella hannai* (*Elphidiella* zone marker) in the *Rotalia tenerrima* zone, and this is simply explained on the basis of reworking; (3) an angular discrepancy between the deposits just north of Elk River (*Elphidiella* zone) and the thin horizontal terrace materials occurring at and to the north of the cape; (4) as indicated in the discussion above, both faunas are indicative of a very shallow cool water type of environment and one should expect a much greater similarity between the two if they were contemporaneous.

LOCALITIES

USC locality 112. Middle Eocene. Sample from silty shale containing *Amphistegina simiensis* near base of sea bluff one half mile southeast of the lighthouse, Cape Blanco, Oregon.

USC locality 113. Pliocene, Port Orford formation. Sample from gray shale just above the beach level, 2 and 1/10 miles south of the lighthouse, Cape Blanco, Oregon. See fig. 1.

USC locality 114. Pleistocene, Elk River formation, *Elphidiella* zone. Sample from the gray sands 20′ above locality 113. See fig. 1.

USC locality 115. Pleistocene, Elk River formation, *Rotalia tenerrima* zone. Fossil bed near top of sea bluff ½ mile southeast of the lighthouse, Cape Blanco, Oregon. See fig. 1.

SYSTEMATIC DESCRIPTION OF SPECIES

QUINQUELOCULINA AKNERIANA var. BELLATULA Bandy, new variety
Plate 41, figures 1 a–c

Test elongate ovate, small, width about two-thirds length; end rounded; chambers of nearly uniform diameter, subcircular in cross section, successive chambers enlarging regularly in size; sutures little depressed; apertural end without definite neck; aperture terminal, ovate, with simple somewhat triangular tooth. Length, 0.51. mm.; breadth, 0.31 mm.; thickness, 0.21 mm.

The variety differs from *Q. akneriana* d'Orbigny (1846, Foram. Foss. Bass. Tert. Vienne) in having less depressed sutures and from *Q. seminulum* (Linné) in the rounded back and the less rapidly increasing size of the chambers (1758, Sys. Nat. ed. 10).

Holotype.—USC No. 224. *Elphidiella* zone, Elk River fm.

GAUDRYINA ARENARIA Galloway and Wissler
Plate 41, figures 3 a,b

Gaudryina arenaria GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 68, pl. 11, fig. 5; Pleistocene, Calif.—CUSHMAN, 1937, Cushman Lab. Foram. Res., Special Publ. 7, p. 60, pl. 9, figs. 9, 10.—CUSHMAN and MCCULLOCH, 1939, Allan Hancock Pacific Exped., vol. 6, No. 1, p. 91, pl. 8, figs. 2, 3; Recent Alaska to Columbia.—CUSHMAN and GRAY, 1946, Cushman Lab. Foram. Res., Special Publ. 19, p. 2, pl. 1, fig. 1; Pleistocene, Calif.—CUSHMAN and TODD, 1947, Cushman Lab. Foram. Res., Special Publ. 21, p. 5, pl. 1, fig. 11; Recent, Washington.

Gaudryina triangularis CUSHMAN, 1927 (not 1911), Bull. Scripps Instit. Oceanography, Tech. Ser. vol. 1, No. 10, p. 138.—CUSHMAN and MOYER, 1930, Cushman Lab. Foram. Res. Contr., vol. 6, p. 52, pl. 7, fig. 5; Recent, Calif.—CUSHMAN, STEWART and STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 51, pl. 1, fig. 2; Pliocene (?), Calif.

Test moderately elongate, initial end bluntly pointed, early triserial portion triangular with blunt carinate edges and somewhat concave sides, later biserial portion comprising about one-half of the length of the test, subrectangular in end view; wall moderately rough in some specimens to very rough and coarse in others; aperture a small arched opening at the base of the inner mar-

gin of the last chamber. Length, 0.65 mm.; breadth, 0.43 mm.; thickness, 0.27 mm.

Plesiotype.—USC No. 241, *Clementia* zone, Port Orford fm.

TEXTULARIA ABBREVIATA d'Orbigny
Plate 41, figures 2 a,b

Textularia abbreviata D'ORBIGNY, 1846, Foram. Fossiles Vienne, p. 249, pl. 15, figs. 9–12; Miocene, Vienna Basin.—FORNASINI, 1887, Boll. Soc. Geol. Ital., vol. 6, pl. 11, figs. 1, 3.—CUSHMAN and MCCULLOCH, 1940, Allan Hancock Pacific Exped., vol. 6, No. 2, p. 116, pl. 13, figs. 1a–c; Recent, off Calif., Mexico and Galapagos.

Test short, subrhomboidal in side view, edge rounded in later portion, nearly subacute in the early portion; chambers five to about eight pairs, increasing rapidly in height as added, wider than high and slightly inflated; sutures distinct, depressed slightly, slightly curved downward toward the outer margin; wall coarsely arenaceous but smoothly finished; aperture a low arched opening at the inner margin of the last chamber. Length, 0.80 mm.; breadth, 0.80 mm.; thickness, 0.55 mm.

Plesiotype.—USC No. 244, *Clementia* zone, Port Orford fm.

MARGINULINA GLABRA d'Orbigny
Plate 41, figures 5 a,b

Marginulina glabra D'ORBIGNY, 1826, Ann. Sci. Nat., Vol. 7, p. 259, No. 6; Modeles, No. 55.—CUSHMAN, 1923, U. S. National Museum, Bull. 104, pt. 4, p. 127, pl. 36, figs. 5, 6; Recent, Atlantic Ocean.—CUSHMAN and PONTON, 1932, Florida State Geol. Surv., Bull. 9, p. 59, pl. 8, figs. 11a, b; Miocene, Florida.—ELLIS and MESSINA, 1940, Catalogue of Foraminifera, Special Publ. 1–34, Amer. Museum of Nat. Hist.

Test elongate, tapering, circular in cross section; early portion planispiral, later portion rectilinear; chambers of uncoiled portion slightly inflated; sutures gently curved in the early planispiral portion, curved and oblique in the rectilinear part, becoming nearly transverse in the later portion; aperture terminal on the outer margin of the last septal face, round and radiate. Length, 1.17 mm.; diameter, 0.37 mm.

Plesiotype.—USC No. 242, *Clementia* zone, Port Orford fm.

DENTALINA BAGGI Galloway and Wissler
Plate 41, figure 9

Nodosaria pauperata BAGG, 1912 (not d'Orbigny), Bull. 513, U. S. Geol. Survey., p. 57, pl. 16, figs. 2a–f; Pleistocene, San Pedro, California.

?*Nodosaria calomorpha* BAGG, 1912 (not Reuss), idem, p. 53, pl. 15, fig. 3; Pleistocene, San Pedro, California.

Dentalina baggi GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 49, pl. 8, figs. 14, 15; Pleistocene, Palos Verdes Hills, Calif.—CUSHMAN and GRAY, 1946, Cushman Lab. Foram. Res. Spec. Publ. 19, p. 13, pl. 2, figs. 26, 27; "Pliocene" (Pleistocene), Timms Point, California.

Test large, elongate, slightly curved, nearly circular in cross section, initial end round, in some forms slightly larger than the immediately succeeding chambers; chambers closely appressed, somewhat inflated, gradually increasing in size; sutures depressed, limbate, somewhat oblique; wall smooth, finely perforate; aperture terminal, produced, round, radiate, situated near the concave side of the test. Length, 2.00 mm.; diameter, 0.54 mm.

Plesiotype.—USC No. 238, *Clementia* zone, Port Orford fm.

FISSURINA LUCIDA (Williamson)
Plate 41, figures 12 a,b

Entosolenia marginata Montagu, var. *lucida* WILLIAMSON, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 17, pl. 2, fig. 17; Recent, British Isles.

Lagena lucida REUSS, 1862, (1863), Sitz. Akad. Wiss. Wien, vol. 46, pt. 1, p. 324, pl. 2, figs. 25, 26.—CUSHMAN, 1923, U. S. Nat. Mus., Bull. 104, pt. 4, p. 33, pl. 6, figs. 1, 2; Recent, Atlantic Ocean.—COLE, 1931, Florida State Geol. Surv. Bull. 6, p. 40, pl. 7, figs. 5, 6; Pliocene and Pleistocene, Florida.—CUSHMAN, 1941, Contr. Cushman Lab. Foram, Res., vol. 17, p. 36, pl. 9, fig. 12; Pleistocene, Alaska.—CUSHMAN, 1948, Cushman Lab. Foram. Res., Special Publ. 23, p. 63, pl. 7, fig. 2; Recent, Arctic.

Test elongate, ovate in side view, rather broadly elliptical in apertural view; wall smooth, finely perforate, aperture an elongate slit-like opening extending into an entosolenian tube. Length, 0.27 mm.; breadth, 0.22 mm.; thickness, 0.12 mm.

Plesiotype.—USC No. 236, *Rotalia tenerrima* zone, Elk River fm.

POLYMORPHINA OREGONENSIS
Bandy, n. sp.
Plate 41, figures 4 a,b

Test elongate, ovate in cross section, apex bluntly pointed, sides nearly parallel, maximum width of test near upper end; edge round, periphery somewhat lobate; sutures moderately oblique, depressed, slightly curved; chambers about three biserially arranged pairs forming most of the adult test, early portion of test composed of about three chambers arranged in a high spire; wall smooth, finely perforate; aperture terminal, radiate. Length, 1.30 mm.; breadth, 0.50 mm.; thickness, 0.33 mm.

Holotype.—USC No. 246, *Clementia* zone, Port Orford fm.

NONIONELLA BASISPINATA
(Cushman and Moyer)
Plate 41, figures 7 a,b

Nonion pizarrense W. Berry, var. *basispinata* CUSHMAN and MOYER, 1930, Cushman Lab. Foram. Res., Contr., vol. 6, p. 54, pl. 7, figs. 18a, b; Recent, California.

Nonion pizarrense W. Berry var. *basispinatum*, CUSHMAN, 1939, U. S. Geol. Survey Prof. Paper 191, p. 25, pl. 6, fig. 28; Recent, Calif.—CUSHMAN and MCCULLOCH, 1940, Allan Hancock Pacific Expeditions, vol. 6, No. 3, p. 158, pl. 17, figs. 8, 9; pl. 18, figs. 4, 5; Recent, from Alaska to Ecuador, incl. Gulf of Calif.—CUSHMAN and GRAY, 1946, Cushman Lab. Foram. Res., Spec. Publ. 19, p. 25, pl. 4, figs. 33–35; Pleistocene, Calif. (Timms Point).—CUSHMAN and TODD, 1947, Cushman Lab. Foram. Res., Spec. Publ. 21, p. 12, pl. 2, fig. 12; Recent, Washington.

Test ovate in side view, periphery smooth; elliptical in edge view; edge abruptly rounded; umbilici small, smooth, with fringe of papillae; chambers 11 to 12 in the last whorl, elongate, increasing rapidly in height, more involute on one side; sutures little depressed, with papillae along the inner portions; wall smooth, unornamented except for the papillate character of the sutures and the inner ends of the chambers in the last whorl; apertural face smoothly convex, aperture a narrow slit at the base of the septal face. Length, 0.65 mm.; breadth, 0.50 mm.; thickness, 0.26 mm.

Examination of the apertural view of the type figure reveals a marked offset of the last chamber from the plane of coiling. The specimens studied herein exhibit some variation in this respect—varying from those only slightly offset to those with a pronounced offset and distinctly more involute on one side. Therefore, this species is placed in the genus *Nonionella*.

Plesiotype.—USC No. 243, *Clementia* zone, Port Orford fm.

NONIONELLA MIOCENICA
Cushman
Plate 41, figures 6 a–c

Nonionina auris CUSHMAN (not d'Orbigny), 1926, Cushman Lab. Foram. Res. Contr., vol. 1, pt. 4, p. 91, pl. 13, figs. 4a–c; Miocene, Calif.

Nonionella miocenica CUSHMAN, 1926, Cushman Lab. Foram. Res. Contr., vol. 2, pt. 3, p. 64; upper Miocene, Calif.—CUSHMAN, STEWART and STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 61, pl. 8, figs. 6a–c; Pliocene, Calif.—CUSHMAN, 1939, U. S. Geol. Survey Prof. Paper 191, p. 31, pl. 8, fig. 9; Miocene, Calif.; Recent, off coast of Mexico.—CUSHMAN and MCCULLOCH, 1940, Allan Hancock Pacific Expeditions, vol. 6, No. 3, p. 161, pl. 18, fig. 1; Recent, shallow water, Alaska to Costa Rica.

Test broadly ovate in side view, narrowly so in edge view; dorsal side partially involute with part of the early spire showing; ventral side involute with umbilicus concealed by raised, lobate extension of the last chamber; 8–10 chambers in the last whorl; sutures slightly curved, only slightly depressed; wall smooth, finely perforate; aperture low, elongate at the base of the apertural face with a tendency to extend onto the ventral side under the lobe of the last-formed chamber. Length, 0.35 mm.; breadth, 0.24 mm.; thickness, 0.17 mm.

Plesiotype.—USC No. 247, *Clementia* zone. Port Orford fm.

ELPHIDIUM GRANULOSUS
(Galloway and Wissler)
Plate 41, figures 8 a,b

Polystomella striato-punctata H. B. BRADY, 1884, (not Fichtel and Moll), Rep. Voy. Challenger, Zool., vol. 9, p. 733, pl. 109, fig. 22 (not fig. 23).—BAGG, 1912, U. S. Geol. Survey Bull. 513, p. 92, pl. 27, figs. 10, 11 (not fig. 12).

Themeon decipiens GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 83, pl. 12, figs. 15, 16 (given as *Themeon granulosa* on plate key); Pleistocene, Palos Verdes Hills, Calif.

Themeon granulosus GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 193.

Test nautiloid, bilaterally symmetrical, tending to become evolute, periphery

slightly lobulate, edge rounded; chambers about nine in the last whorl, embracing nearly to the umbilicus which is covered by granular material; sutures slightly curved, little depressed, with numerous elongate pores and with about 10 to 15 septal bridges on each side; wall with a rather granular appearance due to conspicuous and closely spaced perforations; aperture composed of a row of pores at the base of the last septal face. Diameter, 0.75 mm.; thickness, 0.25 mm.

The figured specimen is a gerontic form in which the last chambers are decreasing in size. In the early portion of the figure and in ephebic individuals the chambers increase more rapidly in length.

Plesiotype.—USC No. 230, *Rotalia tenerrima* zone, Elk River fm.

ELPHIDIUM HUGHESI
Cushman and Grant
Plate 41, figures 11 a,b

Elphidium hughesi CUSHMAN and GRANT, 1927, Trans. San Diego Soc. Nat. Hist., vol. 5, p. 75, pl. 7, fig. 1; Pliocene, Calif.—CUSHMAN, STEWART and STEWART, 1930, idem, vol. 6, p. 61, pl. 3, fig. 15: Pliocene, Calif.—CUSHMAN, 1939, U. S. Geol. Survey Prof. Paper 191, p. 49, pl. 13, fig. 7.

Test subcircular in side view, sides nearly parallel in edge view, back broadly rounded; umbilici small with several tubercles; periphery lobate in later part of test, entire in early part; chambers about 10 in the last whorl, slightly inflated; sutures slightly depressed, curved to the posterior, about 8 to 10 retral processes per suture in the last whorl; aperture multiple, consisting of small rounded openings at the base of the septal face. Diameter, 0.47 mm.; thickness, 0.21 mm.

Plesiotype.—USC No. 227, *Elphidiella* zone, Elk River fm.

ELPHIDIELLA HANNAI
(Cushman and Grant)
Plate 41, figures 10 a,b

Elphidium hannai CUSHMAN and GRANT, 1927, Trans. San Diego Soc. Nat. Hist., vol. 5, p. 77, pl. 8, figs. 1, 2; Pliocene, Calif.—CUSHMAN, STEWART and STEWART, 1930, idem, vol. 6, p. 62, pl. 3, figs. 16, 17; Pliocene, Calif.

Elphidiella hannai CUSHMAN, 1939, U. S. Geol. Survey Prof. Paper 191, p. 66, pl. 19, figs. 1, 2; Recent, Monterey Bay.—CUSHMAN and MCCULLOCH, 1940, Allan Hancock Pacific Exped., vol. 6, No. 3, p. 177, pl. 20, fig. 11; Recent, shallow water, Alaska to Mexico.—CUSHMAN, 1941, Contr. Cushman Lab. Foram. Res., vol. 17, p. 35, pl. 9, figs. 5, 6; Pliocene or Pleis-

EXPLANATION OF PLATE 41

FIGS. *1*—*Quinqueloculina akneriana* var. *bellatula* Bandy n. sp. ×56. *a*, Side view; *b*, apertural view; *c*, opposite side view; holotype no. 224. (p. 273)

2—*Textularia abbreviata* d'Orbigny. ×30. *a*, Side view; *b*, apertural view; plesiotype no. 244. (p. 274)

3—*Gaudryina arenaria* Galloway & Wissler. ×56. *a*, Side view; *b*, apertural view; plesiotype no. 241. (p. 273)

4—*Polymorphina oregonensis* Bandy n. sp. ×40. *a*, Side view; *b*, apertural view; holotype no. 246. (p. 275)

5—*Marginulina glabra* d'Orbigny. ×30. *a*, Side view; *b*, apertural view; plesiotype no. 242. (p. 274)

6—*Nonionella miocenica* Cushman. ×115. *a*, Side view; *b*, edge view; *c*, opposite side; plesiotype no. 247. (p. 275)

7—*Nonionella basispinata* (Cushman & Moyer). ×40. *a*, Edge view; *b*, side view; plesiotype no. 243. (p. 275)

8—*Elphidium granulosus* (Galloway & Wissler). ×40. *a*, Side view; *b*, edge view; plesiotype no. 230. (p. 275)

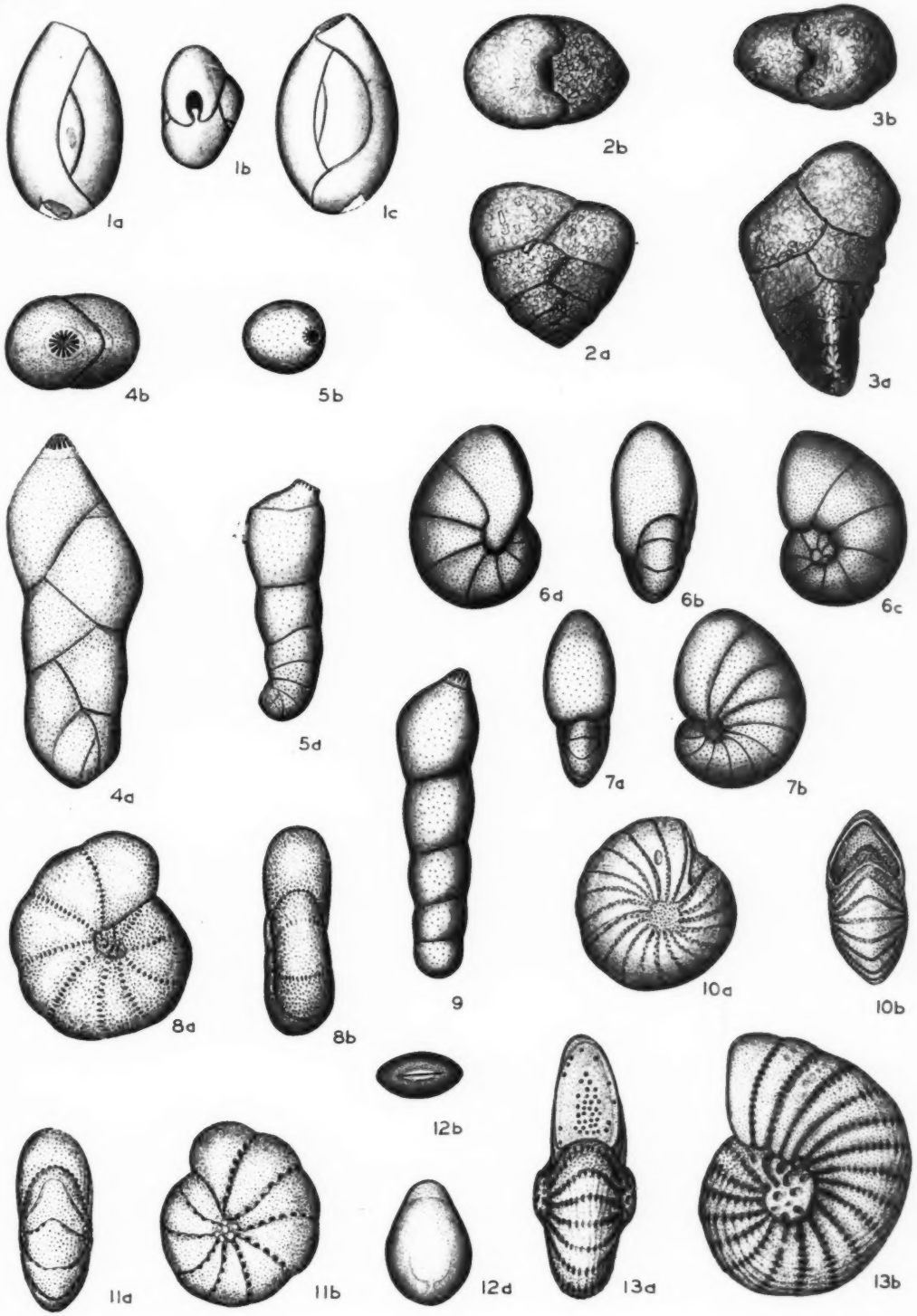
9—*Dentalina baggi* Galloway & Wissler. ×23. Side view; plesiotype no. 238. (p. 274)

10—*Elphidiella hannai* (Cushman & Grant). ×23. *a*, Side view; *b*, edge view; plesiotype no. 225. (p. 276)

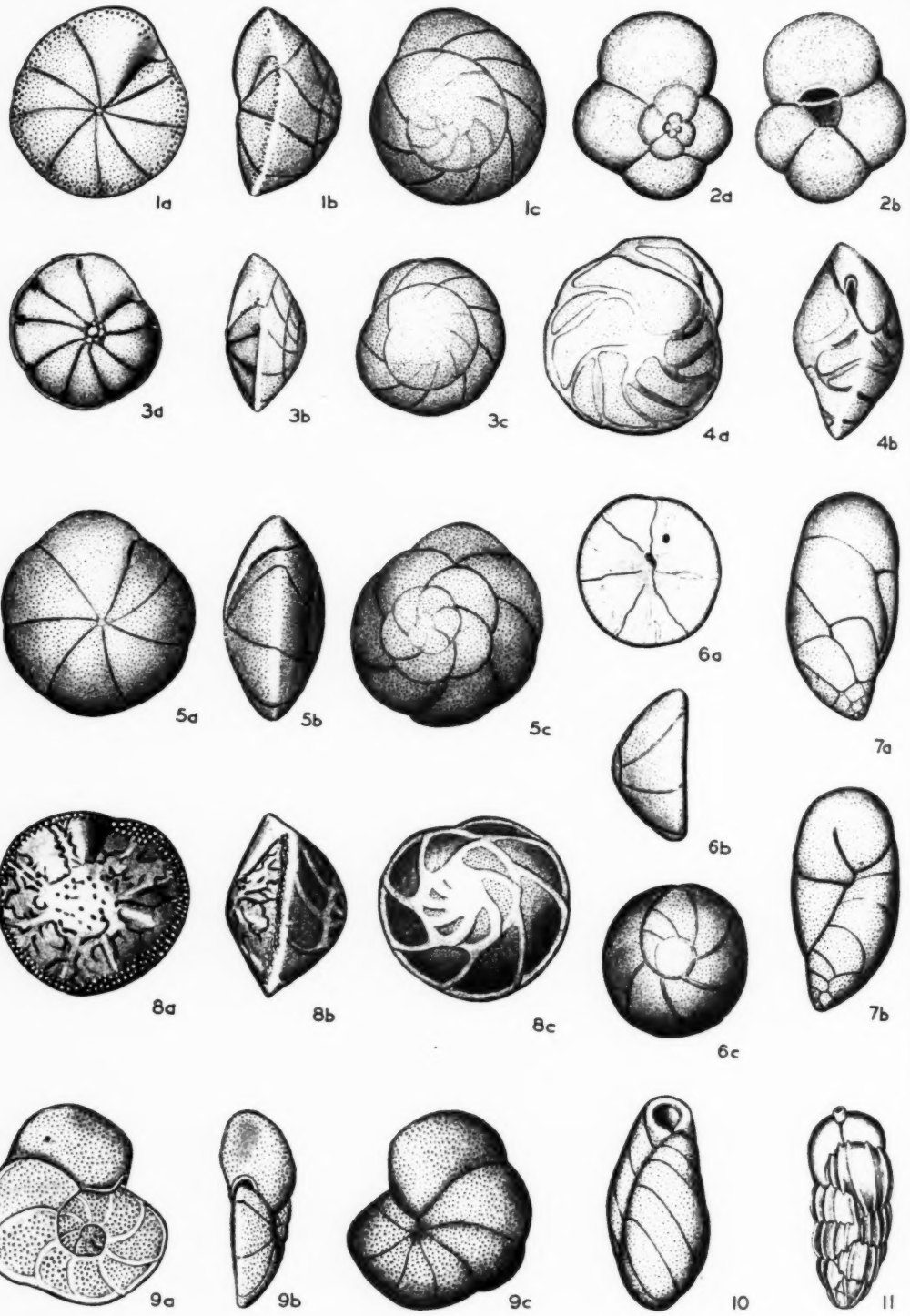
11—*Elphidium hughesi* Cushman & Grant. ×56. *a*, Edge view; *b*, side view; plesiotype no. 227. (p. 276)

12—*Fissurina lucida* (Williamson). ×56. *a*, Side view; *b*, apertural view; plesiotype no. 236. (p. 274)

13—*Elphidiella oregonensis* (Cushman & Grant). ×23. *a*, Edge view; *b*, side view; plesiotype no. 226. (p. 277)



Bandy, Oregon Later Cenozoic Foraminifera



Bandy, Oregon Later Cenozoic Foraminifera

tocene, Alaska.—CUSHMAN and TODD, 1947, Cushman Lab. Foram. Res., Special Publ. 21, p. 15, pl. 2, fig. 22; Recent, coastal waters of Washington.

Elphidiella nitida CUSHMAN, 1941, Contr. Cushman Lab. Foram. Res., vol. 17, p. 35, pl. 9, fig. 4; Pliocene-Pleistocene, Alaska.

Test of medium size for the genus, lenticular; edge abruptly rounded; umbilical regions flattened, with clear secondary shell material and fine perforations, chambers 16–20 in the last whorl, closely appressed; sutures distinct, limbate, flush, with irregular to staggered biserial pores; surface smooth; aperture consisting of fine pores along the base of the apertural face. Diameter, 1.5 mm.; thickness, 0.5 mm. Abundant in *Elphidiella* zone.

E. nitida is placed in synonymy with *E. hannai* inasmuch as the only distinction is the amount of surface polish along with finer pores in the former and these features may be functions of preservation.

Plesiotype.—USC No. 225, *Elphidiella* zone, Elk River fm.

ELPHIDIELLA OREGONENSIS
(Cushman and Grant)
Plate 41, figures 13 a,b

Elphidium oregonense CUSHMAN and GRANT' 1927, Trans. San Diego Soc. Nat. Hist., vol. 5, p. 79, pl. 8, fig. 3; Pleistocene, Oregon.—CUSHMAN, STEWART and STEWART, 1930, Trans. San Diego, Soc. Nat. Hist., vol. 6, p. 62, pl. 4, figs. 1, 2; Pliocene, Calif.—CUSHMAN, 1939, U. S. Geol. Survey Prof. Paper 191, p. 50, pl. 13, figs. 14–16.

Elphidiella oregonense, CUSHMAN, 1941, Cushman Lab. Foram. Research Contr., vol. 17, pt. 2, p. 34, pl. 9, figs. 7–9; Pleistocene or Pliocene, Alaska.

Test large, complanate, subcircular in side view, periphery smooth for the most part, becoming slightly lobulate in the last portion of the final whorl in larger individuals; edge rounded; umbilical region umbonate with central plugs of clear shell material which are coarsely pitted; chambers closely appressed, about 20 in the final whorl; sutures flush at the periphery and becoming somewhat depressed toward the inner portion, with 8 to 10 septal bridges on one side of the test in the early part increasing to about 18 along the sutures in the later part of the last whorl; septal bridges of successive sutures form lines that spiral outward from the umbonal region; sutural pores varying from an irregular single row to a double row; aperture a series of pores on the last septal face. Diameter, 1.7 mm.; thickness, 0.67 mm; common.

Plesiotype.—USC No. 226, *Elphidiella* zone, Elk River fm.

EPONIDES BLANCOENSIS
Bandy, n. sp.
Plate 42, figures 1 a–c

Test subcircular in dorsal view, biconvex, dorsal side more convex; edge angled, pe-

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EXPLANATION OF PLATE 42

FIGS. *1*—*Eponides blancoensis* Bandy n. sp. ×56. *a*, Ventral view; *b*, edge view; *c*, dorsal view; holotype no. 239. (p. 277)

2—*Globigerina bulloides* d'Orbigny. ×115. *a*, Dorsal view; *b*, ventral view; plesiotype no. 229. (p. 279)

3—*Rotalia tenerrima* Bandy n. sp. ×40. *a*, Ventral view; *b*, edge view; *c*, dorsal view; holotype no. 232. (p. 278)

4—*Cassidulina limbata* Cushman & Hughes. ×56. *a*, Side view; *b*, edge view; plesiotype no. 228. (p. 280)

5—*Eponides frigidus* (Cushman). ×76. *a*, Ventral view; *b*, edge view; *c*, dorsal view; plesiotype no. 240. (p. 278)

6—*Discorbis ornatissimus* var. *oregonensis* Bandy n. var. ×40. *a*, Ventral view; *b*, edge view; *c*, dorsal view; holotype no. 231. (p. 279)

7—*Robertina californica* Cushman and Parker. ×56. *a*, Back view; *b*, apertural view; plesiotype no. 245. (p. 280)

8—*Rotalia subcorpulenta* Bandy n. sp. ×27. *a*, Ventral view; *b*, edge view; *c*, dorsal view, holotype no. 233. (p. 278)

9—*Cibicides lobatus* (d'Orbigny). ×56. *a*, Dorsal view; *b*, edge view; *c*, ventral view; plesiotype no. 234. (p. 279)

10—*Buliminella elegantissima* (d'Orbigny). ×110. Side view; plesiotype no. 237. (p. 279)

11—*Uvigerina bradyana* Cushman. ×56. Side view; plesiotype no. 235. (p. 280)

riphery smooth, very slightly lobulate in the later portion of the last whorl; about two and one-half to three whorls in the test; about eight chambers in the final whorl, enlarging gradually, closely appressed; dorsal sutures flush, oblique, slightly curved, narrowly limbate; ventral sutures nearly radial, slightly curved and little depressed; wall smooth, finely perforate excepting for a series of coarse perforations bordering the edge of the ventral side of the test; aperture a very narrow low slit at the base of the last septal face, not observable in all specimens. Diameter, 0.50 mm.; thickness, 0.28 mm.

The distinctive series of coarse perforations bordering the edge on the ventral side separate this form from many similar forms such as *E. antillarum* (d'Orbigny).

Holotype.—USC No. 239, *Clementia* zone, Port Orford fm.

EPONIDES FRIGIDUS
(Cushman)
Plate 42, figures 5 a–c

Pulvinulina karsteni BRADY (not Reuss), 1864. Trans. Linn. Soc. London, vol. 24, p. 470, pl, 48, fig. 15.—1878, Ann. Mag. Nat. Hist., ser. 5, vol. 1, p. 436, pl. 21, fig. 11.

Pulvinulina frigida CUSHMAN, 1921 (1922), Contr. Canadian Biol., p. 144.

Eponides frigida CUSHMAN, 1931, Bull. 104, U. S. Nat. Mus., pt. 8, p. 45.—1941, Contr. Cush. Lab. Foram. Res., vol. 17, p. 37, pl. 9, figs. 16, 17; Pleistocene or Pliocene, Alaska.—CUSHMAN and TODD, 1947, Cushman Lab. Foram. Res., Special Publ. 21, p. 21, pl. 3, fig. 20; Recent, Washington.

Test equally biconvex; edge bluntly angled; periphery slightly lobulate; six to seven chambers in the last whorl, about three whorls in the test; chambers of uniform shape, gradually increasing in size as added, very slightly inflated; spiral suture narrowly limbate; dorsal sutures obliquely curved, flush with the surface, ventral sutures nearly radial and nearly flush; aperture a narrow low slit at the base of the last chamber. Diameter, 0.39 mm.; thickness, 0.20 mm.

Plesiotype.—USC No. 240, *Clementia* zone, Port Orford fm.

ROTALIA SUBCORPULENTA
Bandy, n. sp.
Plate 42, figures 8 a–c

Test large, strongly biconvex, more so dorsally, subcircular in dorsal view; periphery smooth, edge angled with secondary thickening; seven to nine chambers in the last whorl, about two and one-half whorls in the test; umbilicus occupied by large complex punctate plug; surface irregularly channeled on ventral side, breaking up into coarse papillae near the edge, dorsal surface smooth; sutures oblique and slightly curved on dorsal side with coarse heavy limbations of secondary thickening which fuse in the early portion; ventral sutures radial and nearly straight, nearly obscured by the complex channeling of the surface; aperture a low narrow slit at the base of the last septal face. Diameter, 1.37 mm.; thickness 0.65 mm.

This species resembles "*Eponides*" *columbiensis* (Cushman) Contr. Cushman Lab. Foram. Res., vol. 1, p. 43, pl. 7, figs. 1a–c, differing from that form however, in the much thicker test and in the channeled rather than papillate character of most of the ventral side.

Holotype.—USC No. 233, *Rotalia tenerrima* zone, Elk River fm.

ROTALIA TENERRIMA
Bandy, n. sp.
Plate 42, figures 3 a–c

Test nearly circular, biconvex, periphery slightly lobulate, edge angled with narrow rim of clear shell material; umbilicus with low rounded bosses; usually about three and one-half whorls in the test, 8 to 10 chambers in the last whorl; dorsal sutures somewhat oblique and slightly curved, ventral sutures depressed, nearly radial, with very fine papillae along the inner portions, especially characterized by the presence of about 8 to 15 conspicuous tubules or perforations near the peripheral termination of the sutures; aperture a series of pores at the base of the last septal face. Diameter, 0.56 mm.; thickness, 0.30 mm.

This species bears some resemblance to forms which have been designated *Eponides peruviana* (d'Orbigny) (see Cushman, Stewart, and Stewart, 1930, Trans. San Diego Soc. of Nat. Hist., vol. 6, No. 2) but differs from d'Orbigny's species in the presence of the ventral bosses in the umbilical area and in the presence of the distinct tubules near

the peripheral terminations of the ventral sutures.

Holotype.—USC No. 232, *Rotalia tenerrima* zone, Port Orford fm.

DISCORBIS ORNATISSIMUS var. OREGONENSIS Bandy, n. var.
Plate 42, figures 6 a–c

Test of medium size, plano-convex, ventral side flat and slightly umbilicate, circular in dorsal view; edge abruptly rounded, periphery smooth; chambers about five in the final whorl, about one and one-half whorls in the test; sutures broadly limbate dorsally, oblique and curved; ventral sutures radial, nearly obscured by radial channeling; wall with fine to medium perforations dorsally, ventral surface with fine intricate radial channeling; aperture mostly obscure, an irregular slit or opening toward the umbilicus on the ventral side. Diameter, 0.55 mm.; thickness, 0.28 mm.

This variety may be readily distinguished from *D. ornatissimus* Cushman (1925 Contr. Cush. Lab. Foram. Res., vol. 1, p. 42) by the lack of coarse puncta on the dorsal side, five chambers in the last whorl, and a channeled rather than papillate ventral surface.

Holotype.—USC No. 231, *Rotalia tenerrima* zone. Elk River fm.

CIBICIDES LOBATUS (d'Orbigny)
Plate 42, figures 9 a–c

Truncatulina lobata D'ORBIGNY, 1839, in Barker, Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, "Foraminifères," p. 134, pl. 2, figs. 22–24; Recent, Canaries.

Truncatulina lobatula D'ORBIGNY, 1846, Foraminifères fossiles du bassin Tertiare de Vienne, p. 168, pl. 9, figs. 18–23; middle Miocene, Vienna Basin.

Cibicides lobatulus CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 52, pl. 22, fig. 4 (not 5 and 6); upper Eocene, southeastern U. S.

Cibicides lobatus GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, pp. 64, 65, pl. 11, fig. 1; Pleistocene, Calif.—GALLOWAY and HEMINWAY, 1941, New York Acad. Sci., Sci. Survey Porto Rico and the Virgin Islands, vol. 3, pt. 4, p. 393, pl. 24, figs. 4a–c; middle and upper Oligocene, and lower Miocene, Porto Rico.—BANDY, 1949, Bull. Amer. Paleontology, vol. 32, No. 131, p. 105, pl. 19, figs. 3a–c; Eocene and Oligocene, Alabama.

Test planoconvex, much compressed, dorsal side flat or concave, ventral side moderately convex; edge acute, periphery moderately lobate; sutures curved, flush, limbate dorsally, depressed ventrally and less curved; wall coarsely perforate; aperture at base of septal face on periphery with slight lip above, extending on dorsal side along spiral suture for a distance of two or three chambers. Diameter, 0.49 mm.; thickness, 0.17 mm. Rare.

Plesiotype.—USC No. 234, *Rotalia tenerrima* zone, Elk River fm.

GLOBIGERINA BULLOIDES d'Orbigny
Plate 42, figures 2 a,b

Globigerina bulloides D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 277, No. 1; Modeles No. 76 Recent, Adriatic Sea.—GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 40, pl. 7, fig. 4; Pleistocene, Calif.—HOWE and WALLACE, 1932, Louisiana Dept. Cons., Geol. Bull. 2, p. 73, pl. 10, fig. 10; Upper Eocene, La.—GALLOWAY and HEMINWAY, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and the Virgin Islands, vol. 3, pt. 4, p. 411, pl. 29, figs. 1a, b; middle Oligocene, lower Miocene, Porto Rico.—BANDY, 1949, Bull. Amer. Paleontology, vol. 32, No. 131, p. 119, pl. 23, figs. 5a–c; upper Eocene, Oligocene, Alabama.

Test longer than wide, consisting of two and one-half to three whorls arranged in a low, helicoid spire; chambers about 12 in number, inflated, somewhat appressed, subglobular, rapidly enlarging, about three and one-half to four in the final whorl; sutures much depressed ventrally, less dorsally; wall rather coarsely reticulate; aperture a large semicircular opening in the central umbilicus with distinct upper lip. Length, 0.36 mm.; breadth, 0.30 mm.

This is a typical form commonly assigned to *G. bulloides* and displays an apparent variation from three and one-half to four chambers in the final whorl.

Plesiotype.—USC No. 229, *Elphidiella* zone, Elk River fm.

BULIMINELLA ELEGANTISSIMA (d'Orbigny)
Plate 42, figure 10

Bulimina elegantissima D'ORBIGNY, 1839, Voyage dans l'Amérique méridionale, vol. 5, pt. 5, Foraminifères, p. 51, pl. 7, figs. 13, 14; Recent, west coast of South America.

Buliminella elegantissima CUSHMAN, 1919, U. S. Nat. Mus. Proc., vol. 56, p. 606; idem, 1928, Bull. 100, vol. 4, p. 168.—1925, Cushman Lab. Foram. Res. Contr., vol. 1, pt. 2, p. 40, pl. 6, figs. 5a, b; Recent, British Columbia.—CUSHMAN and PARKER, 1946, U. S. Geol. Survey

Prof. Pap. 210-D, p. 67, pl. 17, figs. 10–12; Eocene to Recent.

Test small, fusiform to pyriform, two or three whorls, initial end blunt; chambers narrow, elongate, 7 to 10 in the final whorl; sutures little depressed, curved; wall smooth, finely perforate; aperture oval at the top of the septal face. Length, 0.25 mm.; breadth, 0.14 mm.

Only one specimen of this form was found and it may be a young specimen for the apertural character differs from that of the typical form.

Plesiotype.—USC No. 237, *Clementia* zone, Port Orford fm.

ROBERTINA CALIFORNICA Cushman and Parker
Plate 42, figures 7 a,b

Robertina californica CUSHMAN and PARKER, 1936, Cushman Lab. Foram. Res. Contr., vol. 12, p. 97, pl. 16, figs. 14a, b; Pliocene, Santa Barbara and Pleistocene "Pliocene" of Timms Point, California.—CUSHMAN and PARKER, 1946, U. S. Geol. Surv. Prof. Paper 210-D, p. 74, pl. 18, fig. 11.

Test about twice as long as broad, initial end subacute, apertural end broadly rounded, chambers closely appressed, increasing rather rapidly in size in the final whorl, which consists of about eight pairs of chambers, all of the chambers of one series reach the middle line on the ventral side; sutures limbate, little if at all depressed; aperture a narrow elongate slit extending more than halfway up the septal face, slightly curved; supplementary aperture very low and narrow. Length, 0.58 mm.; breadth, 0.29 mm.

Plesiotype.—USC, No. 245, *Clementia* zone, Port Orford fm.

CASSIDULINA LIMBATA Cushman and Hughes
Plate 42, figures 4 a,b

Cassidulina limbata CUSHMAN and HUGHES, 1925, Cushman Lab. Foram. Res. Contr., vol. 1, pt. 1, p. 12, pl. 2, fig. 2; Pleistocene, Calif.—GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 78, pl. 12, fig. 12; Pleistocene, Calif. —CUSHMAN, STEWART, and STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, p. 74, pl. 6, fig. 7; Pliocene, Calif.—KLEINPELL, 1938, Miocene Stratig., Calif., p. 333, pl. 9, fig. 21; Miocene, Calif.—CUSHMAN and GRAY, 1946, Cushman Lab. Foram. Res., Spec. Publ. 19, p. 42, pl. 7, figs. 14–16; Pleistocene, Calif.

Test subcircular in side view, the last chamber slightly projecting; with central umbos of clear shell material; periphery slightly lobulate, with carina; five to six pairs of chambers in the last-formed coil, tibia-shaped; sutures broadly limbate; wall smooth, finely perforate; aperture elongate parallel to the plane of coiling with irregular lip. Diameter 0.52 mm.; thickness, 0.30 mm.

Plesiotype.—USC No. 228, *Elphidiella* zone, Elk River fm.

UVIGERINA BRADYANA Cushman
Plate 42, figure 11

Uvigerina peregrina CUSHMAN var. *bradyana* CUSHMAN, 1925, U. S. Nat. Mus. Bull. 104, pt. 4, p. 168, pl. 42, fig. 12; Recent, Atlantic Ocean.—CUSHMAN, STEWART, and STEWART, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, No. 2, p. 69, pl. 5, fig. 12; Pliocene, Humboldt Co., Calif.

Test elongate, sides nearly parallel, more than twice as long as broad; periphery lobate; chambers inflated, about three to a whorl throughout; sutures depressed; wall ornamented with medium longitudinal costae, about 6 to 10 per chamber terminating at the sutures; aperture round, terminal, with short neck and lacking a lip. Length, 0.50 mm.; diameter, 0.22 mm.

Plesiotype.—USC No. 235, *Rotalia tenerrima* zone, Elk River fm.

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NEW FORAMINIFERA FROM THE TYPE MEGANOS FORMATION (EOCENE) OF CALIFORNIA

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ABSTRACT—Two new species of Foraminifera are illustrated and described from Division E of the type Meganos formation (Eocene) of California: *Elphidium* (?) *clarki* and *Operculina campi*. This is the earliest stratigraphic occurrence of *Operculina* in California, and if *E.* (?) *clarki* is correctly allocated, possibly one of the earliest occurrences of *Elphidium* in North America.

NO DETAILED published reports are available on the foraminiferal assemblage of the type Meganos formation (Clark and Woodford, 1927) of central California although Schenck (1933), Berthiaume (1938), and Laiming (1940a–b; 1943) have noted some characteristic species from these Eocene beds. Pending the compilation of a comprehensive report on the foraminiferal fauna of this unit, the writer wishes to present descriptions and illustrations of two significant species which are restricted to Division E of the type Meganos formation. Division E, the youngest of the five divisions of the Meganos formation, falls within foraminiferal zones B-3(?), B-4 and C of the Eocene in California.

The specimens upon which *Elphidium* (?) *clarki* and *Operculina campi* are based were obtained from augered holes east of Kellogg Creek in the Byron quadrangle. In addition, surface occurrences also are listed under the systematic description of each species. Examination of samples from shales of Division C in the lower part of the Meganos formation has revealed that the two foraminifers do not occur in that unit. Division C is not present in the Kellogg Creek area due to its being overlapped by Division D, but it does occur further west in the Byron and Mt. Diablo quadrangles.

Acknowledgments.—The writer is indebted to Mr. A. J. Solari of the Geological Division of the Standard Oil Company of California, San Francisco, for supplying the material from which the type specimens are described, and to Mr. Boris Laiming of the Paleontological Department of The Texas Company, Los Angeles, for information concerning the stratigraphic occurrence of *Elphidium* sp. in Zone B-3 of the Eocene of California.

The illustrations were drawn by Mr. M. B. Stephenson of Houston, Texas, and Mr. W. B. Schwarz of Berkeley, California.

Repository of type specimens.—The specimens illustrated and described in this paper have been deposited in the type collections of the University of California, Museum of Paleontology, Berkeley, California.

Family NONIONIDAE
Genus ELPHIDIUM Montfort, 1808
ELPHIDIUM (?) CLARKI Graham, n. sp.
Text figures 1 a–b

Test biconvex, slightly compressed, periphery broadly rounded, except for final two chambers which tend to become flattened; nine or ten uniformly shaped chambers in last-formed whorl, nearly equal in size, earlier ones indistinct owing to cover of granular material on peripheral and lateral sides of test; wall finely perforate, smooth except for papillae; granulate microstructurally; radial sutures flush, limbate, gently curved with a single row of slightly developed, evenly spaced spine-like interruptions which apparently are "tubules" that do not reach the surface in the form of pores; definite bridge-like retral processes not developed; aperture obscured, owing to papillated surface of apertural face; but in specimens in which the last-formed chamber has been broken, a series of very small pores is visible, under high magnification, along the septal face.

Maximum width 0.30 mm.; minimum width 0.27 mm.; thickness 0.19 mm.

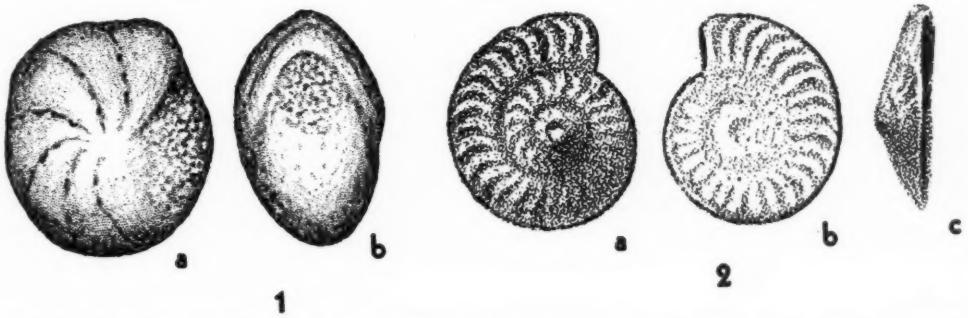
Holotype.—Univ. Calif. Mus. Paleo. no. 35771.

Locality.—Meganos E, Station E-1:2, from augered hole east of Kellogg Creek in the SE¼ SW¼ Sec. 6, T. 1 S., R. 3 E., Byron quadrangle, California. U.S.D.A. aerial photograph BUU-268-60, approximately 300 feet stratigraphically below "white sands" at base of the Ione (?) formation.

Stratigraphic occurrence.—Meganos E.

Remarks.—*Elphidium* (?) *clarki* is distinguished from *E. eocenicum* Cushman and Ellisor of the upper Eocene (Jackson) of Starr County, Texas (Cushman, 1939, pp. 39–40, pl. 10, figs. 18a-b), in being less compressed, in having the earlier formed chambers covered with papillae, and in possessing sutures with retral processes which are not as well developed. It differs from *E. texanum* (Cushman and Applin) from the upper Eocene (Jackson) of Tyler County, Texas (ibid., p. 39, pl. 10, figs. 17 a–b), in being smaller and less compressed, in having fewer chambers of which the earlier formed ones are covered with granular material, and in having flush, not depressed, sutures; instead of a low-arched apertural slit, there is a series of small sutural pores along the septal face. *E.* (?) *clarki* resembles *Nonion tallahattensis* Bandy from the middle Eocene Tallahatta formation (Claiborne) of Little Stave Creek, Clarke County, Alabama (Bandy, 1949, pp. 75–76, pl. 11, figs. 11a–b) but lacks papillate umbilici and nearly straight sutures.

In the upper part of foraminiferal zone B-3 of the Eocene of California, Laiming (1940a, fig. 2, p. 540; 1940b, fig. 2, p. 1924; 1943, fig. 75, p. 194) has found a fossil which he has designated *Elphidium* sp. (as yet not described or figured). Specimens of this fossil sent to the writer by Mr. Laiming contain forms which have sutural patterns identical with those of *E.* (?) *clarki* and others in which sutural pores are definitely present. There can be no doubt that the specimens both with and without the sutural pores belong to the same species and are related to the Meganos E foraminifer. It is possible that Laiming's fossil is a direct descendant of *E.* (?) *clarki*, although it is more compressed, contains five or six more chambers, and does not have the earlier formed chambers covered with papillae.



FIGS. *1, 2—1—Elphidium* (?) *clarki* Graham, n. sp. Holotype, Univ. Calif. Mus. Paleo no. 35771, Station E-1:2. ×105. *a*, side view. *b*, peripheral view. Fig. *2—Operculina campi* Graham, n. sp. Holotype, Univ. Calif. Mus. Paleo. no. 35772, Station E-1:4. ×105. *a, b*, side views. *c*, peripheral view. Both localities are in Division E of the type Meganos formation about 3.25 miles northwest of Byron Hot Springs, California.

Modern textbooks in the field of micropaleontology (Cushman, 1948; Galloway, 1933; Glaessner, 1945) characterize *Elphidium* as having a planispirally coiled and bilaterally symmetrical test with septal bridges (retral processes) and sutures with or without a series of pores. The genus is thought to have evolved from *Nonion* (Cushman, 1939, p. 2; Galloway, 1933, p. 265) with some early or simple species being distinguished with difficulty, in many instances, from species of this latter genus, especially if the septal bridges or sutural pores are not highly developed. Surprisingly enough little attention has been focused, until recently, upon the microstructure of the test wall as a character of taxonomic importance in generic determinations of foraminifers. Wood (1949, p. 243) in studying the test wall of *Elphidium* records that

he has "never found a type with retral processes and a canal system which did not have radially built walls." (Specimens with radially built walls are those which have the vertical crystallographic axis normal to the test wall.)

The Meganos E fossil is granulate, i.e., there is no preferred orientation of the vertical crystallographic axis; and *Elphidium* sp. of Laiming, which in some cases has the same type of sutural pattern as *E.* (?) *clarki* and in other cases has sutures with well-developed pores, is likewise granulate. Wood undoubtedly would consider such specimens to be *Nonion* inasmuch as they do not have a radial structure. However, if this criterion is used as a basis for the allocation of the Meganos fossil to *Nonion*, it would involve a revision of the genus since *Nonion* is not characterized by sutural pores.

Elphidium (?) *clarki* is tentatively referred to that genus solely on the basis of its sutural pattern, and if further structural studies of the "sutural pore type" of *Elphidium* should result in a redefinition of the group, then the species may have to be reallocated.

E. (?) *clarki* is rare in the sandy and silty shales of Meganos E. Many specimens have the final chamber broken, thus affording an opportunity to view the apertural pores which, however, are visible only under high magnification. Under low magnification the sutural and apertural patterns are indistinct, and this species may easily be mistaken for a *Nonion*. *E.* (?) *clarki* occurs throughout the 470 foot section of Meganos E at Kellogg Creek (in which is included the type locality of the species) and has been found in exposures of this division along; (1) the east bank of Oil Creek in the west central part of the NW¼ SE¼ sec. 11, T. 1 N., R. 1 E.; (2) north of Dry Creek highway in the SW¼ SW¼ sec. 16 (the latter samples are probably correlative with those from Laiming's Zone C which were collected a short distance to the west in sec. 17); and (3) along the west bank of the north-south highway in the north central part of the NW¼ SE¼ sec. 17 (the same locality on which Laiming's Zone B-4 is based in this area). Localities 2 and 3 are in T. 1 N., R. 2 E., Mt. Diablo quadrangle.

At its type locality *E.* (?) *clarki* is associated with *Alabamina wilcoxensis* Toulmin, *Anomalina umbonata* Cushman, *Bulimina macilenta* Cushman and Parker, *Cassidulina globosa* Hantken, *Cibicides martinezensis* Cushman and Barksdale, *C. spiropunctatus* Galloway and Morrey, *C. venezuelanus* Nuttall, *C. whitei* Martin, *Eponides lodoensis* Martin, *E. primus* Martin, *Globigerina bulloides* d'Orbigny, *G. triloculinoides* Plummer, *Globorotalia naussi* Martin, *G. nicoli* Martin, *G. rex* Martin, *Gyroidina octocamerata* Cushman and Hanna, *Lagena acuticosta* Reuss, *Marginulina subbullata* Hantken, *Nodosaria latejugata* Gümbel, *Nodosaria longiscata* d'Orbigny, *Nonion florinense* Cole, *N. mauricensis* Howe and Ellis, *N. planatum* Cushman and Thomas, *Pseudoglandulina conica* (Neugeboren), *Robulus pseudovortex* Cole, *Schenckiella gracillima* (Cushman and Bermudez), *Siphonina wilcoxensis* Cushman, *Spiroplectammina adamsi* Lalicker, *Uvigerina lodoensis* Martin, *Vaginulinopsis alticostatus* (Cushman and Barksdale), *Valvulineria involuta* Cushman and Dusenbury, *V. scrobiculata* (Schwager) and other typical Eocene species.

If *E.* (?) *clarki* is correctly allocated then its presence in both Zone B-4 and in Zone C of the type Meganos formation establishes it as the earliest stratigraphic occurrence of the genus in California, for hitherto *Elphidium* has not been recorded from strata older than Laiming's Zone B-3. In the normal stratigraphic sequence of foraminiferal zones in the Eocene of California, Zones B-4 and C underlie Zone B-3. Previous to Laiming's discovery of *Elphidium* sp. in Zone B-3, *E. schencki* and *E. smithi*, both of Cushman and Dusenbury, from the Poway conglomerate (Laiming's Zone A-3), were the oldest known species.

In the Gulf Coast region the earliest occurrence of *Elphidium* is believed to be *Elphidium* n. sp. of Feray from the Weches formation (lower Claiborne) of Texas (Helen Jeanne Plummer, personal communication, 1949). In the eastern coastal plain *E. cynicalis* Jennings from the Hornerstown formation (lower Wilcox) of New Jersey is the oldest known species.

Thus, if the Meganos E is lower Eocene (Wilcox) in age, as some stratigraphers (Weaver et al., 1944; Stewart 1949) think it to be, then *E.* (?) *clarki* may become one of

the earliest species of the genus in North America.

This species is named in honor of the late Professor Bruce L. Clark of the University of California at Berkeley.

Family CAMERINIDAE
Genus OPERCULINA d'Orbigny, 1826
OPERCULINA CAMPI Graham, n. sp.
Text figures 2a, b, c,

Test compressed, modified wafer or disc-shaped, with narrow keel or margin cord, one side slightly convex, the other side flat; nearly three complete whorls on the convex side, slightly more than one whorl visible on the flat face owing to portion of an earlier whorl or whorls showing through the vitreous central part of that side of the test; about twenty-five uniformly shaped "bent finger-like" chambers in last-formed whorl which broaden slightly in approaching periphery; septal sutures recurved, limbate, raised, especially on the convex side of test, coalescing with keel; aperture indistinct.

Maximum width 0.29 mm.; minimum width 0.25 mm.; thickness 0.07 mm.

Holotype.—Univ. Calif. Mus. Paleo., no. 35772.

Locality.—Meganos E, Station E-1:4, from an augered hole east of Kellogg Creek in the SE¼ SW¼ sec. 6, T. 1 S., R. 3 E., Byron Quadrangle, California, U.S.D.A. aerial photograph BUU-286-60, approximately 150 feet stratigraphically below "white sands" at base of the Ione (?) formation.

Stratigraphic occurrence.—Meganos E.

Remarks.—*Operculina campi* occurs sparingly in the sandy and silty shales of Meganos E and usually has the flat side of the test smoothly worn. The species ranges throughout the upper 300 feet of the 470-foot Meganos E section at Kellogg Creek and has been found in surface exposures of Division E along; (1) the stream channel north of the Dry Creek highway in the SW¼ SW¼ sec. 16 (these samples are probably correlative with those from Laiming's Zone C which were collected a short distance to the west in sec. 17); and (2) the west bank of the north-south highway in the north central part of the NW¼ SE¼ sec. 17 (the same locality on which Laiming's Zone B-4 is based in this area). These localities are in T. 1 N., R. 2 E., Mt. Diablo quadrangle.

Operculina campi at the described locality is associated with *Alabamina wilcoxensis* Toulmin, *Angulogerina wilcoxensis* (Cushman and Ponton), *Bathysiphon eocenica* Cushman and Hanna, *Bulimina macilenta* Cushman and Parker, *Cassidulina globosa* Hantken, *Cibicides blanpiedi* Toulmin, *C. judas* (Martin), *C. martinezensis* Cushman and Barksdale, *C. spiropunctatus* Galloway and Morrey, *C. venezuelanus* Nuttall, *C. whitei* Martin, *Elphidium* (?) *clarki* n. sp., *Eponides lodoensis* Martin, *E. primus* Martin, *Gaudryina coalingensis* Cushman and Hanna, *Globigerina bulloides* d'Orbigny, *G. triloculinoides* Plummer, *Globorotalia naussi* Martin, *G. nicoli* Martin, *Gyroidina octocamerata* Cushman and Hanna, *Lagena acuticosta* Reuss, *Lamarckina rugulosa* Plummer, *Marginulina tenuis* Bornemann, *Nodosaria affinis* d'Orbigny, *N. consobrina* (d'Orbigny), *N. jacksonensis* Cushman and Applin, *Nonion florinense* Cole, *N. mauricensis* Howe and Ellis, *N. micrum* Cole, *N. planatum* Cushman and Thomas, *Pseudoglandulina conica* (Neugeboren), *Pseudophragmina clarki* (Cushman), *Robertina angusta* Cushman, *Robulus pseudovortex* Cole, *Siphonina wilcoxensis* Cushman, *Spiroplectammina adamsi* Lalicker, *Uvigerina lodoensis* Martin, *U. wilcoxensis* Cushman and Garrett, *Vaginulinopsis alticostatus* (Cushman and Barksdale), *V. vacavillensis* Hanna, *Valvulineria involuta* Cushman and Dusenbury, *V. scrobiculata* (Schwager) and other typical Eocene species.

The occurrence of *Operculina campi* in Division E (Laiming's Zones B-3 (?), B-4 and C) of the type Meganos formation extends the geologic range of the genus in California. Hitherto, the genus has not been recorded in strata older than Zone B-1 in the Llajas formation and the Sierra Blanca limestone and Anita shale of the middle Eocene.

The species is named in honor of Professor C. L. Camp, Department of Paleontology, University of California at Berkeley.

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JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 3, PP. 287–306, PLS. 43–45, 2 TEXT FIGS., MAY 1950

PALEOZOIC *PTYCHOCLADIA* AND RELATED FORAMINIFERA

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ABSTRACT—Banded and alveolated structure of calcareous wall, manner of partition of chamber, and discovered megalospheric generation for the genus *Ptychocladia*, whose microspheric generation was previously classified with ctenostomatous Bryozoa, indicate its belonging with adnate Foraminifera. New varieties *P. agellus* var. *tenuis* and var. *rotaliformis*, and new species *P. bassleri* from the Pennsylvanian of Nebraska, Kansas and Oklahoma are described. *Chabakovia* Vologdin, a supposed alga from the Middle or Lower Cambrian of southern Urals, is considered related to *Ptychocladia* and the oldest known foraminifer. Another form from the Lower Permian of Russia is provisionally classified as *Chabakovia* (?) *shulgae*, n. sp., and another new species *Bdelloidina* (?) *permica* from the Lower Permian of Texas is described. All mentioned forms and the extant genus *Bdelloidina* are united in a new family Ptychocladiidae. The life-cycle of *Ptychocladia*, and the evolution and ecology of the new family are discussed.

INTRODUCTION

MY INTEREST in the genus *Ptychocladia* arose in connection with research on Paleozoic ctenostomatous Bryozoa (Condra and Elias, 1944), because *Ptychocladia* was originally described by Ulrich and Bassler (1940, p. 89) among them. Although at first the originators of genus *Ptychocladia* placed it with the Bryozoa provisionally only, and seriously considered the possibilities of its belonging to algae or to Foraminifera, in a later classification the position of *Ptychocladia* became unreservedly fixed among ctenostomatous Bryozoa (Bassler, 1913, 1936), though no explanation for the decision was given.

Because *Ptychocladia* appears as a very small and thin crust upon various shells, and can be barely detected without aid from a hand lens, it has been generally overlooked by paleontologists. However, it is of considerable scientific interest being a new type of Paleozoic adnate Foraminifera, as will be shown in this paper.

This conclusion on its nature resulted in a further revision of understanding of other similar problematic fossils, particularly of the interesting remains from the Cambrian of southern Urals, which were described by Vologdin (1939, p. 221) under the name *Chabakovia* and erroneously classified with algae.

The difficulty which has been encountered in recognition of the true nature of these and similar fossil organisms is not surprising, in view of a similar difficulty experienced in understanding of the nature of some extant marine adnate calcareous organisms, which also resemble both Foraminifera and algae; compare investigation of such organisms from the reefs of Funafuti (Chapman, 1900, p. 17).

ACKNOWLEDGEMENTS

I am indebted to Dr. G. E. Condra, Dean and Director of Conservation and Survey Division, University of Nebraska, for placing at my disposal the material collected largely by himself, and in which *Ptychocladia* has been recognized and studied in some detail. Dr. R. S. Bassler, Head Curator of the Department of Geology, U.S. National Museum, kindly verified the generic identity of the material which is here described as *Ptychocladia*, the genus named and originally described by Ulrich and Bassler. Enlarged photographs of glycerine-immersed specimens were sent to Prof. Galloway, of the Department of Geology at the University of Indiana, who agreed that the fossil "looked like a foram. . . . and is well characterized" (letter of July 8, 1945). Dr. McEwan of the University of Nebraska was consulted, and she agreed with placement of *Ptychocladia* with Foraminifera (oral communication). The subsequent discovery of a very small megalospheric generation of *Ptychocladia* was

about as important as the detailed study of its morphology and wall structure, in the final decision to classify the fossil with Foraminifera. The discovered dimorphism was discussed in written communications with Dr. E. H. Myers of Scripps Institution of Oceanography at Los Angeles, California; he also has read and improved the chapter on the Interpretation of Life Cycle.

The microstructure of the wall was a subject of detailed study in coöperation with Dr. Maynard White. To him belongs the credit for recognition of its similarity to the structure of the wall in primitive fusulinids.

Systematic description

Family Ptychocladiidae, new family
Genus Ptychocladia Ulrich and Bassler, 1904, emended

1904. *Ptychocladia agellus* Ulrich and Bassler, Smithsonian Inst. Misc. Coll., vol. 45, no. 1452, pp. 289–290, pl. LXVII, figs. 10, 13.

Diagnosis.—Growth form small, thin, prostrate upon shells of invertebrates, usually consisting of several radiating subequal branches, starting from a common center. Branches occasionally irregularly bifurcating, narrow to broadly transversely expanding, to becoming fan-like; or branches fused into a disk with broadly crenulated periphery. Internally divided into transverse (concentric) chambers by outwardly convex partitions, and the wider chambers may be further "labyrinthically" divided by occasionally developed and subequally spaced radial partitions. Wall is banded and alveolated.

Description.—When Ulrich and Bassler described the original and only known (at that time) species of the genus among the

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Explanation of Plate 43

Bdelloidina, Sagenella, Ptychocladia, and *Chabakovia*

Figs. *1–6*—*Bdelloidina aggregata* Carter. *1, 2.* Holotype, attached to coral *Siderastrea.* External view (*1,* ×abt. 4), and section of a part of the last chamber of same (*2,* ×abt. 40), to show the inside of the last chamber (*a*), "communication hole" (*b*) and "labyrinthic structure" of the outer or "upper wall of the chamber," which is made of coarse sand grains. From Carter, 1877, Pl. XIII, figs. 1 and 7 respectively. *3.* Supposed fossil *B. aggregata,* so identified by Chapman (1900) from the illustrated sketch not prepared by himself and "regarded as adherent to a Cretaceous ammonite." Probably enlarged from the fossil but magnification not indicated. From Chapman (1900, text fig. 1, on p. 9). *4–6.* Outer views of two living specimens showing fine arenaceous texture of outer walls (*4, 5,* ×10), and view of a longitudinal section showing concentric and radial septation, and the character and distribution of pores (*6,* ×30). From Brady, 1884, Pl. XXXVI, figs. 4–6 corresponding to same figure numbers of this plate. (p. 301)

7—*Sagenina frondescens* (Brady), attached to *Cycloclypeus carpenteri* Brady. For comparison with similar branching of test in *Ptychocladia agellus* var. *tenuis* illustrated next to it. From Chapman, 1900, pl. 2, fig. 1, ×5. (p. 293)

8—*Ptychocladia agellus* var. *tenuis* Elias, n. var., attached to the inner of dorsal valve of *Linoproductus.* Pony Creek shale, near top of the Pennsylvanian, 2 mi. NE of Admire, Kansas. ×20. Nebr. Geol. Survey No. 435. (p. 295)

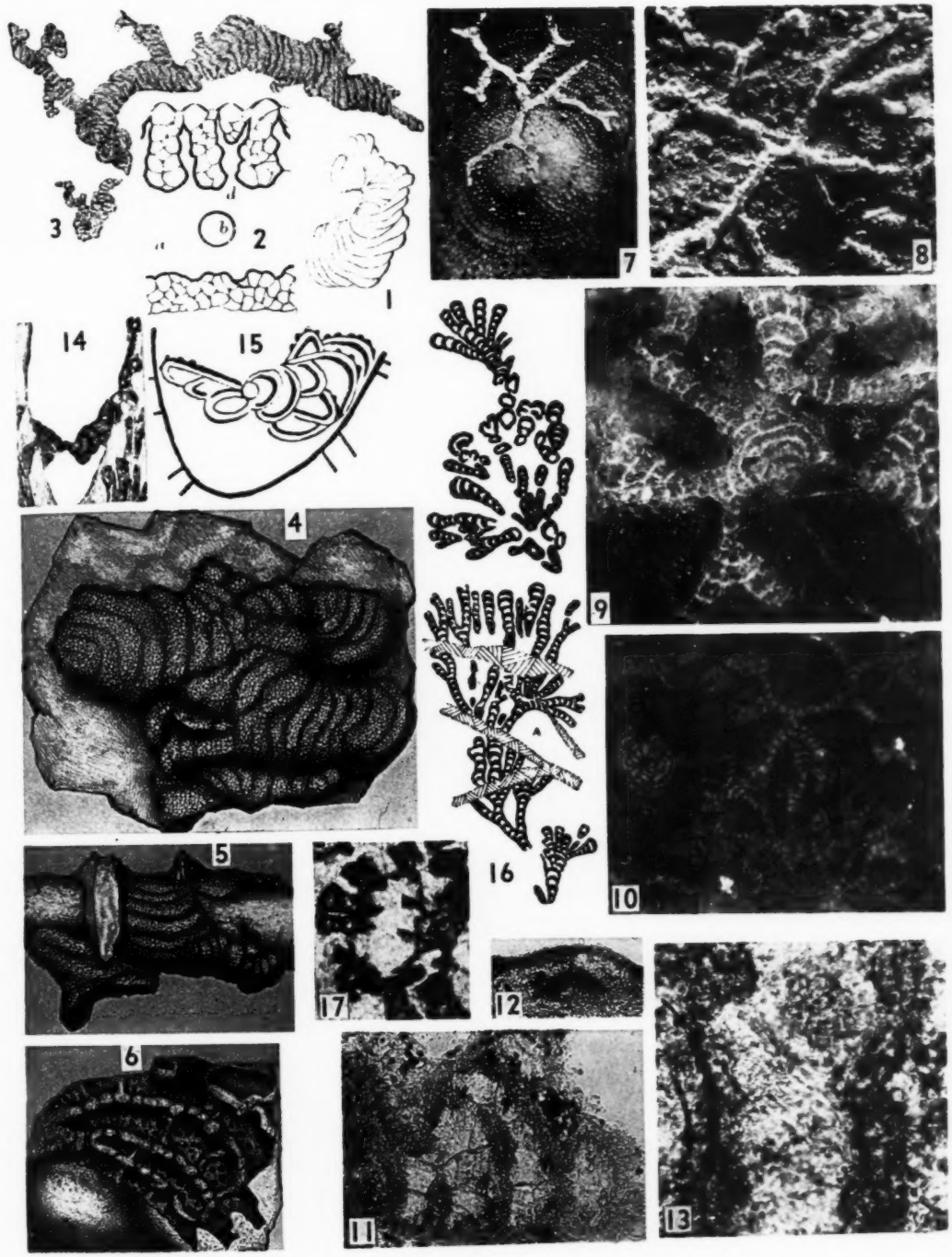
9—*Ptychocladia agellus* attached to the inner side of *Myalina slocomi;* Kanwaka shale, Pennsylvanian, NW of Nehawka, Nebraska. Immersed in glycerine; ×40. Nebr. Geol. Survey No. 439. (p. 295)

10—*Ptychocladia agellus* var. *tenuis* n. sp. and var. *rotaliformis,* n. sp. (marked *a*), attached to dorsal valve of *Chonetes granulifer.* Basal part of Nebraska City limestone, 1 mile NW of Humboldt, Nebraska. Immersed in glycerine; ×20. Nebr. Geol. Survey No. 433. (p. 295)

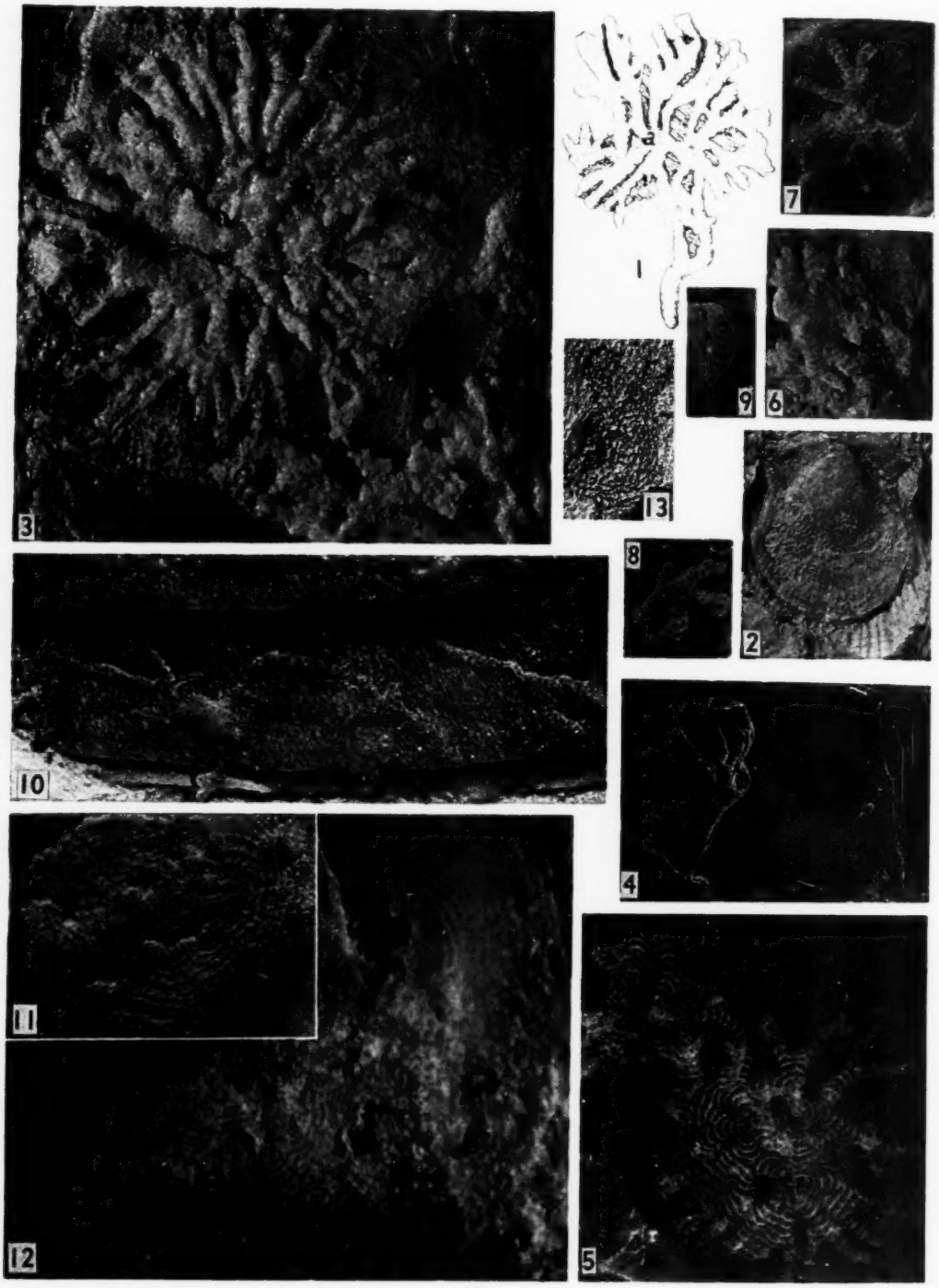
11–13—*Ptychocladia agellus* var. *tenuis,* n. var., attached to *Myalina slocomi;* Tecumseh shale, Shawnee group, Virgil series, Pennsylvania. 18 miles south of Topeka, Kansas. Thin sections parallel (fig. *11,* ×120; fig. *13,* ×400) and perpendicular (fig. *12,* ×180) to the surface of attachment. To show the concentric banding in the wall and the evidence of alveoli in the same. (p. 295)

14–15—*Chabakovia* (?) *shulgae,* n. sp. Holotype, attached to bryozoan *Goniocladia zaleskyi* Shulga. P_1^{1b} zone of the lower Permian, northwestern Ural. *13,* Photograph of a slide, ×20. *14,* Sketch of the same, ×abt. 50. From Shulga-Nesterenko, 1941, pl. LIV, fig. 5 and text fig. 154, on p. 197, respectively. (p. 300)

16–17—*Chabakovia ramosa* Vologdin. Middle Cambrian of Southern Urals. Sketches (*16,* ×10) and photograph (*17,* ×20) of the cotypes. From Vologdin, 1939, text fig. 4 on p. 222, and part of Pl. IX, fig. 3, slightly above its center. (p. 299)



Elias, Paleozoic foraminifer *Ptychocladia*



Elias, Paleozoic foraminifer *Ptychocladia*

ctenostomatous Bryozoa, they cautiously stated that its "systematic position is so doubtful, that we are scarcely willing to hazard an opinion," but added that "possibly they are algae," or "some peculiar type of Foraminifera," or "may be related to some of the preceding forms," that is the described ctenostomatous Bryozoa.

The ultimate choice among these relationships depends, as they state, on whether "their branches are tubular," a point they "did not succeed in determining." However, it is now being determined on ample and satisfactorily preserved material from the Virgil series in Nebraska and Kansas. The new material shows that the branches in *Ptychocladia agellus* are certainly not simple tubes, as they are traversed by the regularly spaced concentric partitions into short chambers, and, besides, in the new species *bassleri*, the chambers are greatly transversely expanded, a feature unknown in the organization of the living or fossil Bryozoa.

The concentric partitions are reflected on the surface by the "transverse wrinkles," which Ulrich and Bassler (1904, p. 290) observed on stems and branches of the original *P. agellus;* they are shown in their sketches (pl. LXVII, figs. 11, 13) more or less regularly spaced, so that their number per given space can be counted: there are about 10 to 12 "annulations" in 1 mm. along a branch, which corresponds well to the widest spacing of the transverse (concentric) partitions in the specimens of *P. agellus* and its var. *tenuis* from Nebraska. Some of our specimens from Nebraska have been sent for examination to Dr. Bassler, who classifies them with the original *P. agellus* (communication to Dr. Condra). The fact that the narrow depressions between the external annulations continue inside as concentric partitions is proved decisively by observation (see pl. 43, figs. 9–13).

The adnate disks of *P. bassleri* n. sp., when well developed, look so much unlike the individuals with the slender radiating branches of *P. agellus* var. *tenuis*, that the two forms could be hardly placed in the same genus, if it were not for the fact that various transitional stages between the two are abundant.

Ulrich and Bassler remark (1904, p. 290) that "the minute structure of these forms is very obscure," and they describe walls of *Ptychocladia agellus* as "apparently composed of structureless, cemented, calcareous grains, which occasionally appear to have been combined so as to have minute pores

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EXPLANATION OF PLATE 44

FIG. *1*—*Ptychocladia agellus* Ulrich and Bassler. Holotype; "Upper Coal Measures" at Springfield, Illinois. After Ulrich and Bassler, 1904, pl. LXVII, fig. 13; enlarged to ×10 from ×9 of the original sketch. (p. 295)

2, 3—*Ptychocladia agellus* Ulrich and Bassler on the outer side of the right valve (*2*), and on the inner side of the left valve of *Aviculopecten exemplarius;* Kanwaka shale, Upper Pennsylvanian, NW of Nehawka, Nebraska. Fig. *2*, ×2; fig. *3*, ×20. Nebr. Geol. Survey No. 434, 431. (p. 295)

4, 5—*Ptychocladia agellus* Ulrich and Bassler, tending toward *P. bassleri* growth form (on the lower left of fig. *5*); on the inner side of *Myalina slocomi;* Tecumseh shale, Upper Pennsylvanian, 18 m. S. of Topeka, Kansas. Fig. *4* ×2; fig. *5* ×20 (same specimen). Nebr. Geol. Survey No. 439. (p. 295)

6–8—*Ptychocladia agellus* Ulrich and Bassler, immature growth forms on the inner side of *Aviculopecten exemplarius;* Kanwaka shale, Upper Pennsylvanian, NW of Nehawka, Nebraska, ×90. Nebr. Geol. Survey No. 443, 438, 438. (p. 295)

9—*Ptychocladia agellus* Ulrich and Bassler, a dwarfed growth form adnate upon a mold of a "vesicle" of *Bascomella gigantea* exposed through dissolution of the inner ostracum of *Myalina slocomi;* Tecumseh shale, Upper Pennsylvanian, NW of Nehawka, Nebraska. ×20. Nebr. Geol. Survey No. 419. (p. 295)

10—*Ptychocladia agellus* var. *tenuis* Elias, n. var. (holotype), on the outside of *Composita ovata;* Plattsmouth limestone, Upper Pennsylvanian, ¼ mile south of Nehawka, Nebraska. ×20. Nebr. Geol. Survey No. 437. (p. 295)

11, 12—*Ptychocladia bassleri* Elias, n. sp., on the inner side of *Myalina slocomi;* Fig. *11*, holotype. Kanwaka shale, Upper Pennsylvanian, NW of Nehawka, Nebraska. ×20. Nebr. Geol. Survey No. 442, 441. (p. 296)

13—*Ptychocladia bassleri* Elias, n. sp., internal mold on the outer side of *Chonetes;* Springer series, NW of Ardmore, Oklahoma. (p. 296)

between them." In the thin sections prepared the wall appears indeed, at low magnification, as indistinctly finely granular; in translucent light it is much darker (impure brownish) than the much more coarsely granular calcite which fills the chambers within the walls. Following is the account of the structure of the wall as seen under higher magnifications.

Microstructure of wall.—In working out the structure of the wall in *Ptychocladia* I have been fortunate to enlist the close cooperation of Dr. Maynard P. White, whose life-long experience with the wall structure in fusulines has proved most valuable in this study.

The following report of the gradual progress in understanding of the nature of the wall in *Ptychocladia* is instructive, as it repeats the familiar pattern of the historical progress in understanding of the wall in fusulines. Just as in the case of the earliest study of the latter, nothing was known about the wall structure in *Ptychocladia* when it was originally described (Ulrich and Bassler, 1904), as no attempt to section this, or other described fossils (the ctenostomatous Bryozoa) was made at that time. Because *Ptychocladia* did not seem to me to belong to the Bryozoa, decision was made to investigate its wall structure. The technique in preparation of thin sections proved somewhat difficult: the test is flattened against the surface of attachment, and because the latter is only approaching a plane, its curvature and other departures from even plane made difficult preparation of a thin section that would comprise more than a fraction of an individual growth form. Also, because *Ptychocladia* is attached to the surface of the prismatic layer of *Myalina*, additional difficulty is added by the tendency of the individual prisms in the latter to split loose from the neighboring prisms under pressure. This fact necessitates lightness of touch when grinding the material down.

The following procedure was used: (1) selection of a specimen as flat as possible, and also the least eroded, and breaking it out of the *Myalina* shell together with as little of this shell as possible; (2) rubbing very gently and for a very short time the exposed surface of *Ptychocladia*, polishing it on a honing stone, and adhering this surface to the ground glass with Canadian balsam on a hot plate; (3) grinding down of the outer part of *Myalina* shell until nearly all of it is gone.

The process of the removal of the last of the prismatic layer of *Myalina* by grinding is very delicate and frequently results in destruction of the *Ptychocladia* test itself. Chemical removal of as much of the last vestiges of *Myalina* substance as possible through painting of an almost finished slide with diluted hydrochloric acid proved effective.

At the end of this work a slide is made of the following parts: (1) central or initial part (if any) of the test, out of which radiate one or more branches; (2) vestiges of the prismatic layer of *Myalina*, partly overlying the test of *Ptychocladia*, and partly filling the space between some portions of its branches; and (3) balsam filling the remaining spaces between these branches.

The process of covering of this combination of the material with cover glass is a very delicate operation, because as soon as the Canadian balsam is liquefied by heat, and after the cover glass is set on top of a slide, the slightest pressure easily breaks the thin section, and tends to produce an overlap of the broken parts upon each other. The greater the thinness of a slide the more likely it will break when floating in Canadian balsam under the pressure of a cover glass.

As the understanding of the complex structure of the wall in *Ptychocladia* gradually progressed, the technique in preparation of its thin sections has been elaborated. In the first, comparatively thick slides prepared, when viewed under small magnification (to $\times 20$ or $\times 30$), the wall appeared granular, though made of calcium carbonate; thus its structure seemed arenaceous, made of coherent fine granules of calcite. This concept of its structure seemed harmonious with the apparent similarity of its general structure with that of *Bdelloidina*, whose wall is arenaceous. At this stage of the research one of the best thin sections was submitted to White for examination, and his observation proved to be a turning point toward correct understanding of the wall structure. White noted that the wall shows evidence of being layered or banded,

and he also observed that there seems to be in it some indications of transverse (radial) porosity. However, so faint are these structural indications that they could be barely observed even by a most experienced eye, and only on some selected parts of the slide. Subsequent photographing of the selected slides in ×120 and ×180 magnifications brought about clearer evidence of the existence of the banding in the wall, but little if any evidence of radial porosity (plate 43, fig. 11, 12), and it seemed to me, at this stage of research, that, although the existence of the banding in the wall proves that *Ptychocladia* belongs to the major group of Foraminifera with *calcareous type of wall*, the problem of possible porosity of the wall would have to be left undecided. However, White expressed his firm conviction that the wall has got to be porous, because the test shows no presence of aperture, an observation, which was clear to us both. I ventured an opinion that perhaps the expected porosity may be in the form of more or less tortuous "labyrinthic" passages between the granules of the wall, that would make them barely discernible in our thin sections; however White insisted that he observed indications of some straight radial canals, even if they are not very distinct, and we cannot prove their existence by photographing. Because of his superior experience in the study of the wall in fusulines, the existence of the radial porosity which he postulated and proved (White, 1932, p. 10) in spite of overbearing opposition to the idea by some American students of fusulines,—I felt obliged to continue attempting preparation of better thin sections, with the hope that they would demonstrate radial porosity if it existed. Some material was also forwarded to White, who agreed to take part in preparation of additional slides. Both of us finally succeeded in making some that were sufficiently convincing to both of us that radial porosity in the wall of *Ptychocladia* is not only a conviction of a logical mind but actually can be demonstrated. The prepared highly magnified photograph (×400; pl. 43, fig. 13) is still not as clearly indicative of this porosity as it can be actually observed by a trained eye, but seems sufficiently convincing. At any rate it shows clearly the presence of some structural differentiation in the direction transverse to the concentric banding of the wall, the banding being exceptionally clearly visible. The black arrow in the figure points to the dark inner band that is clearly differentiated into rhythmically spaced constrictions, that

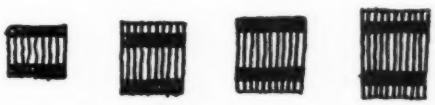

FIG. *1*—Interpretation of the wall structure of *Ptychocladia*, that allows for a three, four or five layered wall, as observed by M. P. White.

give it a bead-like appearance. Each constriction corresponds to a transverse pore, which runs through the transparent band of the wall, but is most difficult to detect. White believes that, similarly to the case of the porosity of the wall in fusulines, the porosity of the wall in *Ptychocladia* could be more clearly demonstrable should we be

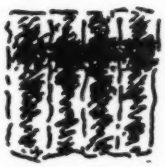

FIG. *2*—Interpretation of the wall structure as observed by M. K. Elias in the course of slight modification of the focusing.

able to find a specimen with limonite filling the transverse pores.

Text figure 1 shows the wall structure of *Ptychocladia* as visualized by White, and text figure 2 is my impression of the structure in the wall photographed on plate 43, fig. 14.

In order to verify our common understanding of transverse porosity we have counted independently and on various thin sections the number of transverse pores per given length within sectioned tests. White used the camera lucida method and obtained an average of ten tubes in .080 mm. from the measurement on two individuals. My measurement with the use of an ocular micrometer indicates an average of ten per .050 to .055 mm., a somewhat smaller figure. White expresses belief that distortion of the edges of the field in the camera lucida

method which he used probably accounts for the discrepancy between our figures. As he explains the measurement of the millimeter, which he used for a scale in the camera lucida, "took up the whole field," and "there is doubtless considerable distortion in such means of measurement" (letter of May 8, 1949). Thus we decided to use the figures obtained by direct count with the help of ocular micrometer, which indicate ten tubes or alveoli per 0.050–0.055 mm. These figures compare well with the number of alveoli counted in the wall of *Fusulina meeki* (Dunbar and Condra) by White (1932, p. 29), and indicate ten alveoli in 0.060 to 0.070 mm.

White considers the whole structure of the wall in *Ptychocladia* comparable to that in fusulines, but representing perhaps more primitive conditions than those in the latter.

Discussion.—The structure of the wall and the variability exhibited by the growth form, as demonstrated by our material of *Ptychocladia*, are quite unlike any observed in the known living or fossil Bryozoa, and therefore it seems reasonably certain that it could not be possibly classified with Ctenostomata, or any other Bryozoa.

There is a considerable external resemblance between *Ptychocladia* and some extant flat, disk-shaped adnate algae of various affinities. Fritsch points out the existence of parallel development of various growth forms which are similar in algae of different affinity, and illustrates it by numerous examples of "Parallelisms in Evolution of Advanced Types of Algal Construction," particularly for Green, Brown and Red Algae (table in Fritsch, 1935, p. 27). Among these he includes "Discoid (prostrate) type," a growth form that resembles *Ptychocladia*. Similarities between these algae and *Ptychocladia* are the general flattening and the manner of division of the prostrate forms into rectangular cells by the two systems of partitions, radial and transverse; and also the tendency toward festoon-like, wide crenulations in the fan-like variety of such growth forms. On the other hand, the following differences can be also observed: the dominance of concentric partitions in *Ptychocladia* is unlike the manner of differentiation in the disk types of any of the living algae, where the radial partitions are invariably dominant, and partitioning is never labyrinthic. Another difference is the larger average size of cells in the fossil genus than in the comparable living algae, although the larger of the variable cells in these living algae approach the normal cell size of *Ptychocladia*. However, these differences are not as important as the fact that the structure of the wall in *Ptychocladia* is unlike the structure of the calcareous crust precipitated by algae. On the other hand, it is quite like the structure of the wall in some Foraminifera, and especially in the primitive fusulines. Further proof of foraminiferal affinity is furnished by the discovery of a megalospheric generation in *Ptychocladia*, an evidence of dimorphism very typical for this order of Protozoa.

There are several Foraminifera which have various characters in common with *Ptychocladia*. Among these are "degenerate" extant (and a few fossil) large Foraminifera, which Cushman classifies in subfamily Neusininae. Most similar to *Ptychocladia* among them are the living *Neusina* and *Jullienella*, both being prostrate and flabelliform to imperfectly disk-like. *Neusina* has very broad chambers, which are pronouncedly outwardly curved as they embrace the preceding chambers. Further indistinct division into transverse chamberlets, as described by Goës (1892) is not unlike that in *Ptychocladia*, *Jullienella* has a striking resemblance to *Ptychocladia* in its complex radial and concentric sculpture, but is quite different from the latter internally. Its interior is divided into long radiating tubes by longitudinal septa, and has no transverse partitions. Both *Neusina* and *Jullienella* are the largest forms among the living Foraminifera, and are about 10 to 50 times as large as *Ptychocladia* both in the overall size and in the size of their chambers. Furthermore, the tests of *Jullienella* and *Neusina* are arenaceous, with siliceous or other kinds of grains bound by chitinous cement, while the test of *Ptychocladia* is calcareous. On the other hand these living genera and *Ptychocladia* have in common abrupt development of one or more distal adventitious uniserial segments at a few points of the broadly curving outer edge of a discoid growth form.

In *Neusina* these distal segments form "irregularly shaped clusters of two or three individuals" (Goës, 1892, p. 196). In *Jullienella* a single similarly located adventitious segment, the base of which consists of several tubes, develops into a fan-shaped growth form. Similar to the latter is the manner of branching in *Ptychocladia*, which frequently consists of two or three adventitious uniserial segments fused together laterally to make a large fan-shaped growth form. The ability to "sprout" or "proliferate" at the curved edge of an adult growth form seems to be unique for *Neusina* and *Jullienella* among the extant Foraminifera. It may be added that these forms have been described but once, are monotypic genera, and their classification among Foraminifera has not been very firmly established. *Jullienella* was originally regarded by its collector, J. Jullien, as a bryozoan (Schlumberger, 1890, p. 211), a historical development not unlike that in the case of the fossil *Ptychocladia*. Moreover, Schlumberger, who described it, compares the shape of *Jullienella* with that of the common Mediterranean brown alga *Padina pavonia*, though concluding that it is a foraminifer related to *Astrorhiza*, but differing in having subdivided chambers. In the discussion on *Neusina* (which is more nearly like *Ptychocladia* than *Jullienella*) Galloway cautiously says (1933, p. 200): "If this genus is a foraminifer it is the largest one known." A few other genera of the *Neusininae*, though placed in this family taxonomically, are questioned by some as possible Bryozoa (*Polyphragma*, so considered by Reuss, see Galloway, 1933; but Cushman, who examined material, claims it is a foraminifer); or calcareous algae (*Stacheia*, so considered by Galloway, 1933). In view of all this it is not surprising that a fossil form, which is similar to the discussed living forms, was so difficult to classify.

Another extant form, which is strikingly similar to *Ptychocladia* is *Cornuspirella diffusa* (Heron-Allen and Earland, 1913; Cushman, 1928, p. 4; 1933, p. 158, pl. 15, fig. 5 and Key, pl. 16, fig. 13). The growth form of the adult stages of this monotypic genus is habitually diversified in the same fashion as the adult growth form of *Ptychocladia*, but its initial coiling is planispiral, like that in *Cornuspira*, as pointed out by Cushman. It differs from *Ptychocladia* also in much larger size, and in having no definite septation of the chambers.

The diffuse adult growth form of *Sagenina frondescens* is very similar to that of *Ptychocladia agellus* var. *tenuis*, n. var. here described, especially in the example illustrated by Chapman (1900, pl. 2, fig. 1; reproduced here on pl. 43, fig. 7). However, the wall in *Sagenina* is "finely arenaceous to subchitinous" (ibid., p. 5), and thus unlike that in *Ptychocladia*, and its chamber is not partitioned.

The comparatively simple, "degenerate" extant and fossil genus *Bdelloidina* is also similar to *Ptychocladia:* it has the same initial manner of development, and the same manner of partition of the chambers, but its test is arenaceous. The comparison of various details in the structure of *Ptychocladia* and *Bdelloidina* is facilitated by the comprehensive description of *Bdelloidina aggregata* by Brady (1884, p. 319, pl. XXXVI, figs. 4–6); his and other published illustrations of *Bdelloidina* are reproduced here (pl. 43, figs. 4–6) for comparison.

Comparison with "Nubecularia."—Establishment of taxonomic units of generic and specific rank among fossil adnate Foraminifera is not an easy problem, even when they are free from matrix, and all characters of their conch, from the initial cell up to the aperture of the living chamber, can be observed. The problem of identification of such Foraminifera, when they are completely immersed and a part of complex fossil crusts, precipitated organically and inorganically, is of course even more difficult. Johnson (1947) has demonstrated the presence of adnate Foraminifera in the Pennsylvanian marine crustose aggregates, which are usually classified under the broad form-genera *Osagia*, *Ottonosia*, and others. However, only transverse cross-sections of the Foraminifera in these crusts have been illustrated by him, and from his sections alone it is difficult to visualize what the whole growth form looks like. In the text it is described thus: "The individuals commonly start with a rounded chamber and to this a number of elongated chambers are added in a straight or sinuous row." Contrary to this, the living and post-Paleozoic

calcareous adnate *Nubecularia* has a coiled planispiral conch (Galloway, 1933, p. 116; Cushman, 1940, p. 183), a fact known and quoted by Johnson (1947, p. 42). Apparently Howchin (1894) was the first to record "*Nubecularia*" in the late Paleozoic rocks (Permo-Carboniferous of Tasmania), and in the same time expanded the meaning of the genus widely, so as to include in it not only planispiral growth forms, but also those with chambers arranged "in rectilinear order, or in irregular acervaline masses." The brief description, not accompanied by illustrations, makes it difficult to incorporate Howchin's material, for which he used the name *Nubecularia*, in the taxonomic synonymy of the latter. In his use of it for certain Paleozoic Foraminifera the name became a very broad designation of a variety of calcareous adnate chambered forms, coiled or variously uncoiled, and obviously it is in this sense that Johnson uses it.

Microstructure of wall has been studied in detail only for a few Foraminifera, other than fusulinids, and calcareous Foraminifera are still classified largely on the evidence of their growth form, aperture, sculpture, and other characters. However, microstructure of wall would be a particularly important character for identification of Foraminifera when only their sections are available; and this is the case with the late Paleozoic "*Nubecularia*" described by Johnson (1947). The fact that magnification up to ×400 was needed in order to learn the essential characters of the type of microstructure in *Ptychocladia*, is indicative of the kind of magnification required for this kind of study. The highest magnification used to show the structure of "*Nubecularia*" is only ×55 (Johnson, 1947, pl. 17, fig. 8), and its wall appears in the photograph black, much like that in *Chabakovia* illustrated by Vologdin (reproduced here on plate 43, fig. 17). It seems that slight indication of banding can be seen in the black wall in the left upper corner of Johnson's plate 1, figure 8, but otherwise the section is not like that of *Ptychocladia*. On the other hand some of his other sections (magnified ×25 to ×35) are not unlike the latter; and also some of the measurements of length and height of the chamber, and of the thickness of the wall (Johnson, 1947, pp. 42–43) are comparable to those in *Ptychocladia*. However, considerable variability of these measurements in "*Nubecularia*" is suggestive of more than one form within this comprehensive designation. Johnson's approach in recording these forms only from their cross-sections, which is similar to his taxonomic treatment of *Girvanella* and other algae, which are associated with them in *Osagia*, though perhaps justified under the circumstances of his study, is only a preliminary step toward better understanding of the variety of the adnate Paleozoic Foraminifera, the investigation of which has just begun.

Comparison with "Wetheredella."—In a similar analysis of micro-organisms in the compound calcareous crusts from the Middle Silurian of England and Baltic region Wood distinguishes tubular Foraminifera from tubular algae by the difference in their wall structure. He finds the wall in algae (*Rothpletzella* and others) is "composed of very small particles of calcite with haphazard arrangement," an aggregate which he calls elsewhere "agal dust," while the wall in *Wetheredella silurica* Wood is "perforated by sparsely set rounded pores normal to the surface," and is "composed of radially set fibres of calcite" (Wood, 1948, pp. 19, 20). No banding of the wall in *Wetheredella* can be observed, and, on the other hand, no "radially set fibres of calcite" can be observed in *Ptychocladia* wall. However, it seems that Wood's "fibers" may be homologous to what are considered here as alveoli in *Ptychocladia*. Wood does not describe dimensions of these structures but in his good photograph, pl. 3, fig. B of the type specimen of *Wetheredella silurica* there can be counted about 3 "fibers" per 2.5 mm. (in 200 magnification), which amounts to 12 per 0.05 mm. or 10 per 0.04 mm. These figures compare closely with those for alveoli in *Ptychocladia* (10 per 0.05–0.055 mm.).

Wood describes the growth form of *Wetheredella* as "composed of subcircular tubes of small diameter (.1 mm. in the typical species), growing concentrically around a foreign body. . . . Tubes branching irregularly, often convex towards the outer surface of the composite mass, moulded below on the substratum." (Wood 1948, p. 20). Thus *Wetheredella* differs from both *Ptychocladia* and Paleozoic "*Nubecularia*" by ab-

sence of transverse septation in its tubes. On the other hand, the diameter of its tubes compares well with the width of the ordinary chambers in *Ptychocladia*, *Chabakovia*, and "*Nubecularia*."

PTYCHOCLADIA AGELLUS Ulrich and Bassler
Plate 43, figure 9; plate 44, figures 1–9; plate 45, figures 1–3

1904. *Ptychocladia agellus* ULRICH and BASSLER, Smithsonian Inst., Misc. Coll., vol. 45, no. 1452, p. 290, pl. LXVII, figs. 10 (part), 13.

Description.—The specific description of the type material is as follows: "Beginning with a comparatively strong, curved stem, .2 mm. to .5 mm. in width, the colony continues its growth by addition of frequently dividing and coalescing depressed convex branches which increase in width from .1 mm. to .2 mm. or more, until an irregularly cribrose expansion, 3 mm. to 5.5 mm. in width, is produced. Basal stem and branches with transverse wrinkles." . . .

In the more nearly complete of the two originally illustrated specimens (see plate 45, figure 1), there is an apparent, even if somewhat irregular radiation of the branches from a common center (at point "a," as indicated). The same type of radiation is observable on practically all of the numerous specimens of *P. agellus* and its varieties from Nebraska, Kansas and Oklahoma. In view of this the concept of the manner of growth in this organism is modified here as distinctly *radial from a common center*. The branches repeatedly bifurcate and coalesce, tending to form large, diamond shaped loops. The branches are slender, and gradually, though not very regularly, increase in width toward the periphery; in their principal parts they usually vary in width from .1 mm. to .2 mm., but at the points of bifurcation and in the peripheral part their width increases up to .5 mm.

Discussion.—The species is generally similar to *P. agellus* var. *tenuis* n. var. from which it differs only in the greater variability of the width of the branches.

Occurrence.—The original material is associated with *Allonema* (?) *minimum*, a ctenostomatous bryozoan on a shell of an unknown invertebrate in the "Upper Coal Measures" near Springfield, Illinois. The exposures in this area are being currently correlated with the upper Des Moines and Missouri series of Nebraska and adjacent states.

The new material comes from near Nehawka, where it is found together with var. *tenuis*. See the details of the occurrence under the latter.

Holotype.—U. S. Nat. Mus. No. 43123, Ulrich and Bassler, 1904, pl. LXVII, fig. 13; by the present (subsequent) designation.

PTYCHOCLADIA AGELLUS var. TENUIS Elias, n. var.
Plate 43, figures 8, 10–13; plate 44, figures 7, 10; plate 45, figure 3

Description.—Adnate stellar structures with radiating, repeatedly bifurcating branches. Initial parts of branches slender or expanding rapidly in width, wedge- or fan-shaped. From the periphery of the latter usually arise several radiating slender secondary branches. These branches in their turn either remain more or less slender and produce bushy growth by frequent bifurcation, or expand into wedge- or fan-shaped forms. All branches repeatedly bifurcate and occasionally coalesce. The branches are transversely divided into cells of subequal height, from 0.1 to 0.13 mm. The width of the cells is much more variable, equaling the width of the branches; usually from 0.1 to 0.2 mm. but at some points of bifurcations increases up to 0.3 mm. The wider cells are invariably outwardly convex.

The adult growth form of the variety measures from 1.5 to 4 mm. in diameter.

Occurrence.—Together with *P. agellus* on the inner and outer surfaces of the valves of *Aviculopecten exemplarius* Newell and on the inner surface of the valves of *Pseudomonotis hawni* (Meek and Hayden). All specimens from a 1″–2″ thick coquinoid bed in the lower part of Kanwaka shale, Shawnee group, Virgil series, at Snyderville quarry, 3 miles west, 1 mile north of Nehawka, Nebraska.

Holotype.—Nebraska Geological Survey No. 433.

PTYCHOCLADIA AGELLUS var. ROTALIFORMIS Elias, n. var.
Plate 43, figure 10a (center of left edge)

Among a number of the observed very variable growth forms of the species there

are two individuals which differ pronouncedly from them all by a compact, radial rotalid disposition of a number of elongated initial cells. This rotalid initial manner of growth is quite unlike the diffuse manner of growth, consisting of a few, uniserial radiating branches, which is typical for *Ptychocladia agellus*. The described individuals are so unlike the typical growth form of the latter species that it could have been classified in a different genus and species. However, its initial rotalid type of growth does not continue beyond first whorl and changes distally into a mixture of concentrically annular (dominating on the lower side pl. 43, fig. 10a) and radiating-ramose (dominating in the upper side pl. 43, fig. 10a) growth types, which are quite comparable to the types of growth displayed by ordinary individuals of *P. agellus* and its var. *tenuis*, for instance by those which are attached on the same shell next to the discussed rotalid-like individual.

The shape and disposition of the initial group of cells which form a complete radiating whorl is reminiscent of the shape and disposition of the initial cells in *Bdelloidina aggregata*, as illustrated by Carter (1877, pl. 1, fig. 1). Cushman (1933, p. 172) reports that he has "recently seen material possibly referable to this genus (*Bdelloidina*), which makes it appear that it may be a degenerate form from some of the rotaliform families." However, perhaps the arrangement of the initial unequal elongated cells in a whorl does not necessarily indicate rotalid feature or relation, as it seems equally reminiscent of "spiral" arrangement of the initial cells in Polymorphinidae, Nonionidae, Peneroplidae, and Lagenidae. An impartial observation of the whorl of the initial cells in the variety discussed would be that they are merely a group of bag-like, elongated cells, whose width and length are quite variable, and a common feature in all is their radiation within the place of attachment from a common center, which is probably a small primary spherical cell or the proloculum.

Holotype.—Nebraska Geological Survey No. 433.

PTYCHOCLADIA BASSLERI Elias, n. sp.
Plate 45, figures 11–12

Description.—Small, flat, dull whitish or grayish disks, single or in groups, are adnate to the surface of some pelecypods, and can be easily mistaken for secondary inorganic mineral crust, which is occasionally developed upon these fossils. The most conspicuous character is the system of outwardly curved and more or less equidistantly spaced partitions, which are disposed concentrically around one or several points in the central part of the disks. There are also transverse partitions, which are usually less conspicuous than the concentric ones, and are somewhat irregularly disposed.

In those disks where more than one center of concentric growth is observed, the similarity of the general plan of structure to that of *P. agellus* is evident. In *P. bassleri* the conch starts from a spherical central cell, and its expansion goes rapidly in form of a very broad wedge or sector with a strongly curved periphery. Usually more than one wedge-shaped branch or uniserial sector grows from a common center. These sectors coalesce to form a solid disk with outwardly directed broad crenulations, which mark the fused wedges or sectors. In some specimens,

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EXPLANATION OF PLATE 45

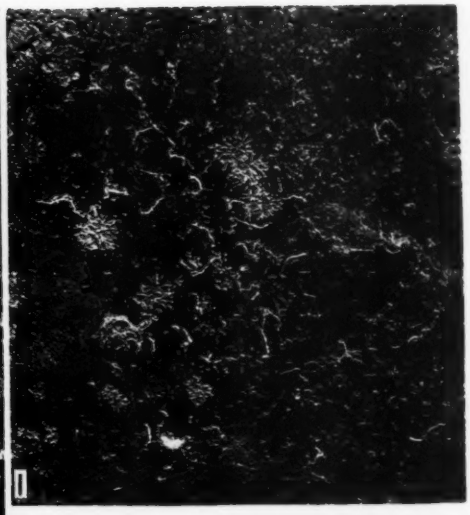
FIG. *1*—*Ptychocladia agellus* Ulrich and Bassler, on the inner side of *Myalina slocomi;* Tecumseh shale, Upper Pennsylvanian, 18 mi. S. of Topeka, Kansas. ×2. Nebr. Geol. Survey No. 440. (p. 295)

2—*Ptychocladia agellus* s. l., megalospheric generation; on the inner side of *Myalina slocomi*, detail of the specimen on pl. 44, fig. *4*, ×20. Nebr. Geol. Survey No. 439. (p. 295)

3—*Ptychocladia agellus* Ulrich and Bassler (above), *P. agellus* ver. *tenuis*, n. var. (below), and megalospheric generation of *P. agellus* s. l. (scattered, mostly on the left side); on the inner side of *Myalina slocomi*, detail of the specimen on pl. 44, fig. *3*, ×20. Nebr. Geol. Survey No. 439. (p. 295)

4—*Bdelloidina* (?) *permica* Elias, n. sp. Limestone in Wolfcamp series (Lower Permian), Glass Mountains, Texas, Cotypes, ×10. Nebr. Geol. Survey No. 455. (p. 302)

5—*Bdelloidina* (?) *permica* Elias, n. sp. Cotype marked *a* on fig. *4*, immersed in glycerine, ×110. Nebr. Geol. Survey No. 455. (p. 302)



Elias, Paleozoic foraminifer *Ptychocladia*

at certain distance from the central cell, adventitious centers of growth appear at the periphery of some broadly curving sectors; the new sectors of growth around each secondary center coalesce over small gaps at their bases and thus the growth of the disk is continued. The youngest (latest) broad concentric chambers tend to go over the crenulations caused by the growth at the several secondary centers with gradually diminishing sags over the points of connections, so that the final outline of the disk becomes nearly circular with almost no crenulations at all.

The height of the broad, concentric chambers usually varies from 0.05 to 0.07 mm., but occasionally becomes as small as 0.03 mm.; the width of the cells between the cross-partitions varies from 0.05 to about 0.3 or 0.4 mm. The thickness of the concentric walls is about 0.015–0.018 mm., and of the transverse walls about 0.010 mm.

Occurrence.—On the inner surface of the valves of *Myalina* (*Orthomyalina*) *slocomi* Sayre, occasionally growing over the stolons and rarely over portions of the vesicles of *Bascomella gigantea* which appears adnate on the same shells. Also together with *Ptychocladia agellus* and its var. *tenuis* on the valves of *Aviculopecten* and *Pseudomonotis*. Coquinoid bed in the lower part of Kanwaka shale, Shawnee group, Virgil series, in Snyderville quarry, 3 miles west, 1 mile north of Nehawka, Nebraska.

An interesting additional occurrence of this discoidal form of *Ptychocladia* was discovered in the course of recent investigation of a prolific invertebrate fauna from the Springer near Ardmore, Oklahoma. The fauna is made largely of external and internal molds of various shells, and on two of these, *Chonetes* n. sp. Elias (MS) and *Composita rotunda* Snider individuals of *Ptychocladia bassleri* are seen attached to the exterior of the outer mold of the valve, see plate 45, figure 13. The test of the adnate foraminifer is gone, but its typical structure can be recognized by the internal mold of its chambers, which have been filled by dense limonite. The concentric growth form, and the manner of partition of its cells, are the same as in *P. bassleri* from Nebraska, but all dimensions are somewhat smaller (pl. 45, fig. 13).

Holotype.—Nebraska Geological Survey No. 442.

List of Occurrences of
Ptychocladia agellus and its varieties

I. Occurrences in Wabaunsee group, Virgil series, Pennsylvanian, of Nebraska and Kansas

1. Pony Creek shale, 2 miles northeast of Admire, Kansas. *P. agellus* occurs in large individuals up to 2½ mm. in diameter that crowd upon the surface of both sides of a complete, though crushed valve of *Chonetes granulifer*.
2. Nebraska City limestone, basal part, 1 mile northwest of Humboldt, Nebraska. *P. agellus* and var. *tenuis* in association with *Ammovertella* (?) adnate on separated valves of *Chonetes granulifer* and *Juresania nebrascensis*.

II. Occurrences in Shawnee group, Virgil series, Pennsylvanian of Nebraska and Kansas

3. Tecumseh shale, 18 miles south of Topeka at Highway U. S. 75. *P. agellus*, var. *tenuis*, *P. bassleri*, and megalospheric generation of *P. agellus*, *sensu lato*, occur alone and in association with *Ammovertella* on the inner side and occasionally also on the outer side of *Myalina slocomi* Sayre; in some cases they occur profusely, particularly *P. bassleri*, which attains a maximum of 2 mm. in diameter.
4. Kanwaka shale, Snyderville quarry, 3 miles west and 1 mile north of Nehawka, Nebraska. *P. agellus* and *P. agellus* var. *tenuis* on inner side of *Aviculopecten exemplarius;* on inner side of left valve and on right (smooth) valve of *Pseudomonotis hawni;* and on inner side of *Myalina* sp. *P. bassleri* on inner side of *Myalina slocomi* in association with doubtful ctenostomatous bryozoan *Bascomella gigantea* (see Condra and Elias, 1944, p. 538–540, pls. 6, 9, 10, and 11); also on fragment of *Promytilus* (?).
5. Plattsmouth limestone of Oread formation, ¼ mile south of Nehawka, Nebraska. *P. agellus* var. *tenuis* on *Composita ovata*.

III. Occurrence in Douglas group

6. Cass limestone, at Burlington quarry, 1 mile north, 1½ west of South Bend, Nebraska. *P. agellus* var. *tenuis* on *Composita ovata.*

IV. Occurrence in Missouri or Des Moines Series in Illinois

7. "Upper Coal Measures" near Springfield, Illinois, currently correlated with the Missouri series or with upper Des Moines series. *Ptychocladia agellus* (holotype and cotype) associated with ctenostomatous bryozoan *Allonema* (?) *minimum* Ulrich and Bassler (see Condra and Elias, 1944, p. 537, pl. 6, fig. 10).

V. Occurrence in Springer series of Oklahoma

8. Springer series, 17 miles NW of Ardmore, Oklahoma. *Ptychocladia bassleri* on outer side of *Chonetes n. sp.* Elias (MS) and *Composita rotunda* Snider.

Genus CHABAKOVIA Vologdin, emended

1939. *Chabakovia*, VOLOGDIN, Problems of Pal., vol. 5, p. 221 (Russian); p. 255 (English).

In one of his valuable contributions to the knowledge of the Cambrian life in Russia, Vologdin describes a series of fossils which he interprets as algae. Among these is *Chabakovia ramosa*, whose similarity to *Ptychocladia*, and particularly to *Ptychocladia agellus* and its variety *tenuis* is striking.

Vologdin's original characteristic of the genus includes some allusions to its supposed algal nature; hence his characteristic is modified here to neutral terms. Otherwise the diagnosis is being kept here as near to that in Vologdin's text as possible:

> The small dendritic growth forms (resembling in the outline some forms of algal genus *Epiphyton* from the same fossiliferous Cambrian limestone), with branches formed by a succession of bulbous calcareous cells. The width of branches variable. Transverse partitions between the chambers in a branch are convex in the direction of growth.

In the specific description of *Chabakovia ramosa* (1939, p. 256) Vologdin intimates that the growth form starts with "a basal bulb," which in the present understanding is a proloculum of this foraminifer.

Genotype.—Chabakovia ramosa Vologdin, from exposure No. 2592, massive light gray Cambrian limestone; Orskii region northeast of river Ertashka, southern Urals, cartographic sheet B-40-10, Latitude 51°, 19, 20′; longitude 57°, 30, 45′; area of limestone outcrops 180×30 meters.

Discussion.—Chabakovia is similar to *Ptychocladia* in character and magnitude of growth form; manner of multiplication of the branches; presence of initial spherical cell; and shape of chambers and manner of their gradual distal increase in width, accompanied by very little, if any increase of height and thickness of wall. Structure of wall in *Chabakovia* has not been investigated in detail, but it is known to be chemically calcareous. It appears nearly opaque and nontransparent in the photographed thin sections, with a faint indication of a lighter band within dark wall.

Vologdin assigns *Chabakovia ramosa* to algae because of its general resemblance to many prostrate or ramose thalli of the latter, such as mentioned here in the preceding discussion on *Ptychocladia* and algae. He justly points out that the general growth form and manner of multiplication in *Chabakovia* are reminiscent of the same in the associated ramose, shrubby fossils, whose reference to algae are at the present left without challenge. Perhaps it would have been futile for Vologdin to compare *Chabakovia* with *Ptychocladia* while the latter was imperfectly known and illustrated only by the outline-sketches furnished by Ulrich and Bassler (1904). However, the present investigation of the new material identified with the original *Ptychocladia* furnishes new information which induced the present revision of the biologic interpretation of *Chabakovia.* Although the exact minute structure of the wall of the latter remains at the present unknown, the remarkable general similarity of the wall, including banding, as well as all other morphological features of *Chabakovia ramosa* and *Ptychocladia agellus* make their interpretation as related Foraminifera, almost certain. They seem to differ only in one respect: *Ptychocladia* is invariably adnate and prostrate on the shells of various invertebrates, while *Chabakovia* is

obviously not prostrate upon shell or any other hard substratum. Although Vologdin does not state directly whether it was an adnate or free organism, the fact that he classifies it with algae and speaks of its "usual upwards growth" indicates his belief in its attachment to substratum at initial area of growth. Vologdin describes the enclosing rock as light gray limestone, with a "dense and massive to brecciated texture." In the photographs of the thin sections the matrix around *Chabakovia* appears fine grained. Vologdin says that the rock is built chiefly by mass accumulation of *Razumovskya* Vologdin and *Epiphyton* Bornemann, which he interprets as calcareous algae of uncertain affinity. It seems that the matrix of the rock is a consolidated fine calcareous ooze, and *Chabakovia* is apparently embedded in it, rather than attached to the just mentioned problematic algae. Indeed, Vologdin says nothing about *Chabakovia* being attached to them or other objects, although he illustrates the preserved initial chamber in many individuals, which are obviously very delicate and fragile. In view of this it seems permissible to conclude that *Chabakovia* was growing freely upon calcareous ooze, much as the mentioned extant foraminifer *Cornuspira*, "when undisturbed is capable of ramifying and spreading over the surface of the ooze," (described by Heron-Allen and Earland, 1913, p. 274).

Vologdin states that the general development of *Chabakovia ramosa* "is one-sided and proceeds commonly upwards," which description, when combined with illustrations, seems to indicate a shrub-like growth form with a considerable lateral spread. The difference in the habitual mode of attachment seems sufficient for generic differentiation between *Ptychocladia* and *Chabakovia*. The change in the mode of attachment from spreading over fine ooze to spreading over the surface of a hard substratum is of apparent mechanical advantage for this fragile dendritic growth form.

Occurrence of *Chabakovia* in the Middle or Lower Cambrian (if the form is admitted among Foraminifera) makes it the oldest known representative of this order of Protozoa. The previous record of the earliest Foraminifera (Cushman, 1933, pp. 45–46; Howell and Dunn, 1942, p. 638; Howell and Sandidge, 1933), has been based on an assemblage of imperfectly preserved Foraminifera, supposedly of Cambrian age, but actually collected from a loose fragment of Lower Jurassic limestone at the Malverns, England (Wood, 1946, p. 447).

CHABAKOVIA RAMOSA Vologdin
Plate 43, figures 16, 17

1939. *Chabakovia ramosa*, VOLOGDIN, Problems of Paleontology, vol. 5, pp. 222–223 (Russian text), pp. 256–257 (English text), pl. II, fig. 4: pl. VII, fig. 3a; pl. IX, figs. 1, 2, 3a; text fig. 4 (on p. 222).

Vologdin's modified description follows: Small growth forms formed by bifurcating to multiple-branching ramuli, more or less spreading in upward direction. Each branch starts with a bulbous cell, to which similar cells are added in uniserial manner, their width being the same, or gradually widens. Thus a branch has a general cylindrical to subconical shape, but is divided inside by transverse partitions, with convexity in direction of growth; these partitions are slightly thicker than the side walls. The whole growth form starts from a basal bulb about 0.1 mm. in diameter. When reaching certain increase in diameter, a branch divides abruptly by ramification into two or three, each starting with a cell of smaller diameter. Branches vary in cross-section from circular to oval to angular outline, from 0.1 to 0.2 mm. in diameter. Angularity is thought to result from crowding of simultaneously developing neighboring branches.

The fossil has not been observed in abundant development, but its growth forms and isolated branches are found scattered among thalli of algal genera *Epiphyton* Bornemann, *Renalcis* Vologdin, and other fossils.

Stratigraphic position.—Vologdin concludes that the limestone, in which *Chabakovia* is found associated with Archaeocyatha and algae, is "Middle Cambrian and partly, probably, higher" (Vologdin, 1939, p. 257). He bases this age assignment on the comparative study of this fossil biota with similar ones which he studied from the Cambrian of Asia. However, Okulitch points out that trilobites and brachiopods, presence of which in association with Vologdin's fossil he anticipates, would be more important and decisive in its age correlation with other

known Cambrian biotas. All known American faunas of Pleospongia (Archaeocyatha) "disappeared with the Lower Cambrian" (Okulitch, 1943, p. 18). It seems to me, however, that this fact does not preclude the possibility of survival of advanced Archaeocyatha into the medial Cambrian, as believed by Vologdin: compare the survival of the genus *Archimedes* into the Uralian and Permian of Russia, and similar cases of other fossil genera (Elias, 1950, p. 142).

Note.—Figures of *Chabakovia ramosa*, reillustrated here on pl. 43, figures 16 and 17 are marked in original publication as magnified ×40 and ×20 correspondingly. But comparison of the two shows that the photograph certainly has a higher magnification than the sketch. Judging by the dimensions of the thickness of the branches given by Vologdin in the text (0.1 to 0.2 mm.) the magnification of the sketch is certainly not 40, but only ×10 or only slightly more, while that of the photograph is ×20, as correctly indicated.

CHABAKOVIA (?) SHULGAE Elias, n. sp.
Plate 43, figures 4, 15

1941. "Spiral body," SHULGA-NESTERENKO, text-fig. 154 on p. 197, and on pl. LIV, fig. 5, adnate and suspended between two branches of bryozoan *Goniocladia zalesskyi* Shulga-Nesterenko (pp. 195–197), in P_1^{1b} zone of the Lower Permian, northwestern Urals, slide no. D252d.

In the monograph on the Permian Bryozoa of Russia Miss Shulga-Nesterenko (1941) describes and illustrates a small organism adnate on *Goniocladia*, but does not record it by name and leaves its classification uncertain. The accurate description and illustration of the fossil seem sufficient for its classification in the same group with *Chabakovia* and *Ptychocladia*, and for its provisional assignment with the former genus, in spite of the great difference in geological age. It is sufficiently different, however, from the known species of both genera to justify its recognition as a new species, *Chabakovia* (?) *shulgae*. Shulga describes the fossil (1941, footnote 2 on p. 196, Russian), as follows:

Inside of one fenestrule (of *Goniocladia*) in thin section No. D252d, the width of which is 1.36 mm., there is enclosed a complex body (fig. 154), which consists of 17 chambers, irregularly overlapping what appears as an initial chamber, and overlapping each other, much like what is seen in transverse section of a spiral foraminifer (pl. LIV, fig. 5) or a tubular shell of a worm (fig. 155).

In explanation to plate LIV, figure 5 (reillustrated here on pl. 43, fig. 14), Shulga says that it represents a section of "a spiral body in the lumen of a fenestrule."

Initial chamber is about 50μ in diam., height of overlapping chamber about 76μ, with thickness of wall 10 to 25μ; heavy black and white concentric bands in the sketch (our pl. 43, fig. 15), seem to indicate, in much generalized form, the banding of the wall faintly visible on the photograph (our pl. 43, fig. 14).

The peculiar attachment of *Chabakovia* (?) *shulgae* by its sides, and not by the initial chamber, seems to indicate free development in its early stages of growth, prior to its apparently incidental lodging between the branches of *Goniocladia*.

Genus BDELLOIDINA Carter

1877. *Bdelloidina* CARTER, Ann. Mag. Nat. Hist., ser. 4, vol. 19, p. 201, pl. 13, figs. 1–8 (Extant; coral reefs).
1884. *Bdelloidina* BRADY, Rep. Voy. 'Challenger,' Zool., vol. 9, p. 319, pl. XXXVI, figs. 4–6.
1900. *Bdelloidina* CHAPMAN, F., Jour. Linn. Soc., Zool, vol. 28, pp. 7–9, text fig. 1; pl. 1, fig. 3.

The suggested inclusion of *Bdelloidina* in the new family Ptychocladiidae necessitates the following discussion of the genus, which clarifies some current discrepancies in regard to its structure.

This adnate monotypic genus was described by its originator in some detail, with an emphasis on perforations in its wall, and a comprehensive discussion of "labyrinthic" canals and labyrinthic structures in this and other Foraminifera. His discussion and the numerous, though somewhat generalized and partly diagrammatic drawings show clearly that by the term *labyrinthic* he means the series of tubular perforations in the outer wall of a chamber (Carter, 1877, pl. XIII, fig. 7, structure indicated *e*, "pore tubulation or 'labyrinthic structure' amidst the sand-grains of the upper wall or roof," see explanation to the plate on p. 209). On the other hand, the term *labyrinthic* is now being differently understood and differently applied, as seen by the following definition by Cushman (1933, p. 16): "in some forms,

especially among the arenaceous group, there is a secondary filling of the chambers resulting in 'labyrinthic' chambers."

This difference in understanding of the term *labyrinthic*, as applied to Foraminifera tests, results in apparent discrepancies in the characteristics given for the same genera by different authors. Thus, *Bdelloidina* is described by Galloway (1933, p. 202) as having the "chambers uniserial, short and wide, labyrinthic inside," while Cushman (1930, p. 172) considers this genus as having the "chambers simple, not labyrinthic," as he places it in his subfamily Placopsilininae, whose chambers are thus characterized.

What complicates understanding of the term labyrinthic (as applied to foraminiferal chamber) still more is the fact that in the description of *Bdelloidina* by Brady, who illustrates the test of this genus in the more accurate and less generalized drawings, than those by Carter, the test of *Bdelloidina* is shown to have not only perforations, termed "labyrinthic" by Carter (and other contemporary writers), but also somewhat irregularly spaced radial partitions, which occupy about the same transverse position as the "secondary filling" of the chambers, that result in labyrinthic chamber, or very near to what is understood under labyrinthic chamber by Cushman; yet Cushman, who reproduces Brady's illustration that shows these transverse (radial) partitions, does not call the chamber labyrinthic, a term which he obviously restricts only to the partitions produced by the "secondary filling."

Leaving out, at the present, the problem as to what should and what should not be called labyrinthic in Foraminifera, it is of some importance to point out here that Brady identifies with *Bdelloidina aggregata* Carter the tests, which in all respects are like the original material, but in addition have also radial partitions, not mentioned or illustrated by Carter. Clearly, therefore, if Brady is right in understanding the genus and the species, its extant representatives may or may not have radial partitions in the chambers. For the sake of the record and convenience of discussion the forms with radial partitions are here designated as *Bdelloidina aggregata* var. *bradii*.

The third author to describe *Bdelloidina aggregata* (Chapman, 1900), quotes the following characteristic of it given by Brady, (1884, pp. 319–20) thus:

> Test adherent, depressed; consisting of a number of closely approximated chambers, arranged more or less regularly in a single, simple or branched, linear series, and intercommunicating by a row of pores on each septal face. Segments very short (on the axis of growth) and broad; curved or irregular in outline; subdivided more or less completely by numerous secondary septa. Walls rough externally, inferior surface smooth. Aperture porous. Diameter of the adherent patches $\frac{1}{8}$ inch [4 mm.] or more.

In his own description of the material Chapman calls the pores in the wall "labyrinthural canals" (Chapman, 1900, p. 8). He does not state or illustrate whether his material has or has not radial partitions. Chapman recognizes for the first time a fossil *Bdelloidina aggregata*, but he does so only on the strength of a drawing "made many years ago" and "in the possession of Prof. Rupert Jones." It has been "regarded as adherent to a Cretaceous Ammonite from Mr. Matthew Wright's cabinet," and the sketch is reproduced by Carter for the first time (Carter, 1900, text fig. 1, on p. 9). Clearly, Carter has not seen the actual specimen, and there is no scale to the drawing reproduced, although it is presumably enlarged. It is republished here (pl. 43, fig. 3) just as Carter published it. No radial partitions are shown on the sketch, but it is apparently an external view on which such partitions could not possibly be shown. Of interest is a clear indication of an initial chamber in the left lower corner of the drawing; the small size of the initial chamber, as compared with the great number of the subsequent chambers seems to indicate the microspheric generation.

Following is a description of a new adnate Permian foraminifer, whose classification with *Bdelloidina* is provisional. The species resembles some examples of the adnate Foraminifera in the Pennsylvanian of Texas and Oklahoma, which have been currently classified with *Stacheia pupoides* Brady, but whose wall structure and manner of chamber partition have not been described. The form here described as *Bdelloidina* (?) *permica* does not seem to have a clearly discernible labyrinthic division of the chambers, and its chambers do not become biseiral in the adult part of the shell, as they do in *Stacheia*

pupoides; on the other hand its silicified walls seem to have the same kind of canals that Carter illustrates for *Bdelloidina aggregata* (pl. 43, fig. 2) and calls "labyrinthic."

BDELLOIDINA (?) PERMICA Elias, n. sp.
Plate 45, figures 4, 5

All specimens are silicified, being obtained by hydrochloric acid etching from a small specimen of limestone. There is hardly any doubt that silicification is secondary, because all other invertebrate fossils, which are normally calcareous and have been also obtained from the same rock, are similarly silicified.

long. External and internal surfaces of wall more or less smooth. The thickness of wall about 0.02–0.03 mm.

All specimens from the brown fossiliferous limestone from the Wolfcamp series (Lower Permian), Glass Mountains, Texas; collected by King and King,

Cotypes.—Nebr. Geol. Survey No. 444.

Interpretation of life cycle.—The discovery of the two well preserved growth forms in the life cycle of *Ptychocladia*, which apparently are the larger, microspheric, and the smaller, megalospheric generations presents an unusually complete combination of the data pertaining to the life history of this

PRINCIPAL DIMENSIONS OF THE DESCRIBED SPECIES (in mm.)

Genera and Species	Chamber			Thickness of Wall	Age
	Height		Width		
	Adult ch.	Young ch.			
Bdelloidina aggregata	.25–.35	.12–.16	.5 –2.0	.06 –.10	Recent
Bdelloidina aggregata	.25	.10	.5 –.2	?	Cretaceous
Bdelloidina permica, n. sp.	.12	.01–.10	.10–.20		Wolfcamp
Chabakovia (?) shulgae, n. sp.		.075	.10–.40	.010–.025	Lower Permian
Ptychocladia agellus	.05–.08	.03	.10–.30	.010–.018	Wabaunsee (latest Pennsylvanian)
Ptychocladia agellus var. *tenuis*, n. var.	.1 –.13		.10–.30		Wabaunsee
Ptychocladia bassleri, n. sp.	.05–.07	.035	.05–.40	.010–.018	Wabaunsee
Chabakovia ramosa	.05–.07	.035	.10–.20	.02 –.03	Middle of Lower Cambrian

Some specimens have been recovered with the substratum silicified and attached to them. In all these cases the substratum was either spines of brachiopods or subcylindrical branches of Bryozoa, so that it appears as if some hard cylindrical surfaces were generally selected for the attachment and development of this foraminifer. However, the ventral or adoral side of the conch, which is invariably concave, does not seem to be a mere reflection of the cylindrical surfaces of the substratum, but is gentler, wider, and more nearly regularly concave, than the convex surfaces of the substratum. The uniserial sequences of the chambers are dorsoventrally compressed, the dorsal side being very gently convex. Height of the chamber varies from 0.03 to 0.1 mm.; width from 0.1 to 0.5 mm. The longest obtained incomplete growth form is about 2.2 mm.

fossil organism, that invites biological interpretation. Thanks to the recent elaborate and accurate investigations on life histories of representative living Foraminifera, chiefly by Myers (1935, 1936, 1938, 1943), and the well established cytologic relationship between microspheric and megalospheric testate rhizopods we seem now in a position to attempt the following analysis, proceeding from the known to unknown.

Myers concludes that in most living species of Foraminifera studied the agamont test is the larger, and that this microspheric generation is non-sexual and multinucleate. Thus we may conclude that the larger, microspheric generation of *Ptychocladia*, which is most numerous, is the agamont.

As Myers further states, the life cycle in an agamont proceeds with an orderly series of nuclear divisions of the diploid nuclei and

is eventually followed by multiple fission of the cytoplasm which "results in as many mononucleate agamonts as there were nuclei produced" (1938, p. 15, explanation of plate). This process may proceed entirely within the microspheric test, including the secretion of test around the young mononucleate megalospheric gamonts (in *Discorbis patelliformis*), or the protoplasmic contents may escape from the microspheric test prior to multiple fission (in *Spirillina vivipara* and *Polystomella crispa*). It appears that in *Ptychocladia* the latter procedure must have taken place, the free amoeboid megalospheric juveniles apparently seeking a place of attachment before formation of the test: the fossil evidence demonstrates numerous attached megalospheric tests in all stages of development, including single prolocula with not more than a trace of the first, very small, chamber. These are found in close proximity to the adnate tests of the microspheric generation on shells of *Myalina*.

The life cycle of the megalospheric agamonts probably proceeded, as it does in other Foraminifera, by an orderly series of nuclear divisions of the equational type followed by a reduction division which produced the gametes or zoospores. In the living Foraminifera the subsequent fertilization of haploid gametes resulting in diploid zygotes takes place between gametes derived from different parent gamonts. Myers established three types of fertilization as follows: (A) In *Spirillina vivipara* and *Patellina corrugata* the agamonts develop within a special cyst built around two or more associated gamonts and composed of "substrate debris and animal cement"; (B) in *Discorbis patelliformis* the fertilization proceeds within the space formed by the dissolution of a portion of the ventral wall and the septa between the chambers of two contacting parent gamonts; and (C) in *Polystomella crispa* the gametes are pelagic, escaping free, and fertilization depends "upon the chance meeting of gametes."

Because the parent gamonts in *Ptychocladia* are attached they could not possibly come in contact and insure fertilization of the types (A) or (B), and there is hardly any doubt therefore that the parent gamonts were free, pelagic, flagellated zoospores, and that their fertilization was dependent on chance meeting in the surrounding water, a procedure that falls under type (C). This conclusion is compatible with the general principles of evolution observed in both Animal and Plant Kingdoms, where primitive fertilization results from a chance meeting of gametes, wastefully produced, and where there is no device which makes for an insured fertilization. Thus in Foraminifera, too, the more primitive method of fertilization must have been apparently that of a chance meeting among the liberally discharged sexual cells.

Taxonomy and evolution.—In classification of a genus among other Foraminifera the following characters usually are considered most important: structure of wall, manner in which chambers are built, added, and partitioned; and general type of growth-form. Two diametrically opposite views are being held, as to which of the two principal kinds of wall structure, calcareous or arenaceous, is primitive, and which is derived. The difference between these two views is complicated by further difference in opinion on the nature of some finely-granular calcareous tests: (1) are they made of foreign (to the Foraminifera) calcareous grains (calcaro-arenaceous, Galloway, 1933), held together by glutinous, chitinous or mineral cement, or (2) is their granular calcium carbonate secreted by the animal itself? If the first explanation applies, the test in question should be considered arenaceous; acceptance of the second explanation would mean that the test is truly calcareous.

As described above, the test in *Ptychocladia* is made of fine calcareous granules apparently secreted by the animal, because the test is distinctly banded and alveolated. Thus it should be understood as a calcareous foraminifer. The similarity of the type of the chambering and growth form, and of the banding of the wall in *Chabakovia* are suggestive that its test is also calcareous.

The general plan and manner of growth of the test have much in common with the same in *Neusina*, *Jullienella*, and *Bdelloidina*, and to less extent in other variably growing tests, which are included in Neusininae (Cushman, 1910, p. 129) by Galloway (1933); and in two different families: Neusinidae (Cushman) and Placopsilinidae

(Cushman) by Cushman (1933). Both Galloway and Cushman consider that all Foraminifera in the mentioned families are arenaceous, some built by coarse and the other by fine grains. If broad relationship of *Ptychocladia* and Ptychocladiidae to comprehensive Neusininae will prove real, it would indicate evolutionary change from calcareous to arenaceous wall in this group of Foraminifera.

If *Ptychocladia* developed from *Chabakovia*, the evolution of the stock was also toward more complete attachment of the adult test, and also development of some radial partitions, toward "labyrinthic" chamber. However, a further step in evolution, from *Ptychocladia* to *Bdelloidina*, was apparently degenerative, as the latter has a simplified, erratically curving and zigzaging test, instead of a radiating and fan-shaped test in both *Chabakovia* and *Ptychocladia*. On the other hand, the internal partitioning of the chamber did not change appreciably from *Ptychocladia* to *Bdelloidina*.

The outlined evolution of the described fossil forms and their inferred relationship to *Bdelloidina* suggest removal of the latter from the previously established phyletic groups and its provisional assignment to the new family Ptychocladiidae for the described, rather primitive phyletic group. Cushman (1933, p. 172) expresses dissatisfaction with the current family assignments of *Bdelloidina*, as he feels that it could be "a degenerate form from some of the rotaliform families," and suggests further study of the genus. Perhaps what Cushman observed in his material is something like the aberrant pseudo-rotaliform development noticed for *Ptychocladia*, and recorded here as *P. agellus* var. *rotaliformis* (see Pl. 43, fig. 10 *a*, at the center of left edge). This seems to be an abortive attempt at coiling in a plane, perhaps thrown out as a biological mutation, that under conditions of prostrate attachment possessed no advantageous innovations for successful competition.

The recent discovery by Grice (1948) of the new genus *Manorella*, related to *Polyphragma* Reuss, induces him to suggest segregation of the two genera in a subfamily Polyphragminae, and to express a belief in impending revision of family Placopsilinidae. His conclusions are complementary to the present decision to remove genus *Bdelloidina* from Placopsilinidae and to include it in the new family Ptychocladiidae. The possibility of breaking the Placopsilinidae into more natural groups was anticipated by Cushman (1933, p. 171), when he said about the forms included in it that "It may be that some of these are more or less degenerate forms, and do not have the same ancestral source, . . . "

Ecological remarks.—The occurrence of the adnate microspheric growth forms of *Ptychocladia* on the inner surface of an eroded shell of *Myalina slocomi* has some particular ecological interest because of its relation to the excavations in this shell described by Condra and Elias (1944, pp. 539–541, pls. 6, 9–11) as *Bascomella gigantea*, a doubtful ctenostomatous bryozoan. In one example the internal mold of a vesicle of *B. gigantea* is overgrown by an imperfectly developed small microspheric individual of *Ptychocladia bassleri*. Because all *Bascomella* vesicles were originally lodged in the inner ostracum of *Myalina*, the sequence of the events subsequent to the death of the organism *Bascomella* apparently has been as follows: (1) hardening of the lodged vesicle through calcification; (2) dissolution of the inner ostracum of *Myalina* and exposure of the petrified vesicles of *Bascomella;* (3) attachment of an agamont of *Ptychocladia* upon the exposed mold of *Bascomella*.

In a number of other examples both generations of *Ptychocladia* are attached upon the inner side of the durable outer ostracum of *Myalina* upon the dissolution of its inner ostracum. These observations indicate that the process of petrification of *Bascomella* preceded the process of dissolution of the inner ostracum of *Myalina*, hence apparently during the life time of the latter mollusk. On the other hand *Ptychocladia* apparently was able to fasten itself upon the molluscan shell only after partial destruction of the shell substance, as they developed upon that part (outer ostracum) of shell, that is made of comparatively stable prismatic calcite. Thus it is clear that *Ptychocladia* was not parasitic, and probably not even saphrophytic, but merely used the discarded and stable remnants of

various shells as a convenient substratum for attachment. Microspheric agamonts were able to use for attachment even the rapidly curving surfaces of the hard molds of *Bascomella*, although they were not able to develop their normal full size growth forms unless the surface of substratum was more or less even: such is provided by the greater parts of the shells of *Myalina*, *Aviculopecten*, and other pelecypods. However, the outer sides of these shells were not as suitable for *Ptychocladia* as the inner sides, because the outer sides have sculpture, either in form of costae (in *Aviculopecten*) or the coarse shingle-like "growth lines" (in *Myalina*). These sculptural features upon the shells used as substratum impeded normal development of *Ptychocladia* growth forms, as evidenced by the stunted examples upon the outer side of *Myalina*. Similarly stunted forms develop upon the convex outer surface of the brachiopod *Linoproductus*, which is sculptured by costae, lines of growth, and scattered spines.

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CHECK LIST OF TERTIARY SMALLER FORAMINIFERA OF JAPAN

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ABSTRACT—From Japan proper 387 species, subspecies and varieties of Tertiary smaller Foraminifera have been described and figured. Most of them are from Pliocene formations; some are from Miocene and Oligocene deposits. This compilation proves the need for more research.

INTRODUCTION

THIS catalogue records all Tertiary smaller Foraminifera which have been described as new or have been figured from Japan proper. The format is the same as the "Check List of Tertiary Larger Foraminifera of Japan" by S. Hanzawa (1947).

Although the Tertiary stratigraphy of Japan has been studied by many authors, differences of opinion still exist as to the interregional correlation of the formations and their geologic ages. The smaller foraminifers are not yet sufficiently known to aid materially in solving the problems of the Miocene-Pliocene and Pliocene-Pleistocene boundaries. The list, therefore, includes formations referred by some authors to the Pliocene and by others to the Pleistocene.

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LOCALITIES AND FORMATIONS

The collecting localities are indicated by letters in text fig. 1 and their exact localities are stated in the text by latitude and longitude with reference to sheet-names of the topographic maps of Japan, scale 1:50,000. The formation names are quoted from the original or later literature.

Quotation marks indicate an exact transcription of the original which is here considered erroneous or doubtful; parentheses indicate the use of quotation marks in the original; square brackets indicate data interpolated by the compiler; TM means topographic map of Japan, 1:50,000 scale, followed by the sheet name.

Loc. A: [River cliff at the junction of Shisenzawa and Zari-gawa, about 150 m. SE of bridge on main road, Horonitachibetsu, Numata-mura, Uryu-gun, Hokkaido. TM Ebishima, Lat. 43°52′N, Long. 141°55′E]. Takikawa formation, Pliocene, K. Asano, 1937b.

Loc. B: (Poronai, Mikasayama-mura, Sorachi-gun, Hokkaido), Exact locality not stated. "Poronai formation," (Cretaceous). Yokoyama, 1890; [Oligocene].

Loc. C-1: [Roadside cliff, about 800 m. SW of Nakano-kawa, Yubetsu-mura, Suttu-gun, Hokkaido. TM Oshoro, Lat. 42°42′N, Long. 140°16′E]. Setana formation, Pliocene, K. Asano, 1938b.

Loc. C-2: [Valley-cliff of Kaigara-sawa, W of Nishino-sawa, Kuromatsunai-mura, Suttu-gun, Hokkaido. TM Oshamambe, Lat. 42°40′ N, Long. 140°17′E]. Setana formation, Pliocene, K. Asano, 1938b.

Loc. C-3: [Valley-cliff of the Toshibetsu-gawa, about 1 km. SE of the Pirica-mine, Toshibetsu-mura, Setana-gun, Hokkaido. TM Imagane, Lat. 42°28′N, Long. 140°13′E]. Setana formation, Pliocene, K. Asano, 1938b.

Loc. C-4: [Valley-cliff of the Toshibetsu-gawa, about 800 m. W of Omagari, Toshibetsu-mura, Setana-gun, Hokkaido. TM Imagane, Lat.

FIG. 1—Map showing the localities of the Tertiary smaller Foraminifera of Japan grouped according to Prefecture.

42°27′N, Long. 140°12′E]. Setana formation, Pliocene, K. Asano, 1938b.

Loc. C-5: [Valley-cliff of the Toshibetsu-gawa, about 500 m. SW of the Hanaishi-station. Toshibetsu-mura, Setana-gun, Hokkaido. TM Imagane, Lat. 42°26′N, Long. 140°11′E]. Setana formation, Pliocene, K. Asano, 1938b.

Loc. C-6: [Valley-cliff of the Toshibetsu-gawa, just beneath the Tsuribashi bridge, Toshibetsu-mura, Setana-gun, Hokkaido. TM Imagane, Lat. 42°25′N, Long. 140°11′E]. Setana formation, Pliocene, K. Asano, 1938b.

Loc. C-7: [Roadside cutting, about 200 m. W of Maruyama, Toshibetsu-mura, Setana-gun, Hokkaido. TM Setana, Lat. 42°25′N, Long. 139°56′E]. Setana formation, Pliocene, K. Asano, 1938b.

Loc. C-8: [Roadside cutting, about 2 km. SSW of Minamikanehara, Toshibetsu-mura, Setana-gun, Hokkaido. TM Setana, Lat. 42°22′N, Long. 139°59′E]. Setana formation, Pliocene, K. Asano, 1938b.

Loc. D-1: [Sea-cliff, about 200 m. W of Anden, Iriai-mura, Minamiakita-gun, Akita-ken. TM Funakawa, Lat. 39°58′N, Long. 139°51′E]. Shibikawa formation, Pliocene, K. Asano, 1939.

Loc. D-2: [Sea-cliff at Oibana-zaki, Wakimoto-mura, Minamiakita-gun, Akita-ken. TM Funakawa, Lat. 39°54′N, Long. 139°54′E]. Wakimoto formation, Pliocene, K. Asano, 1939.

Loc. E: [Roadside cutting about 200 m. SE of Saboyama, Oide-mura, Natori-gun, Miyagiken. TM Sendai, Lat. 38°14′N, Long. 140°49′E]. "Moniwa formation," Miocene, K. Asano, 1937a.

Loc. F: [Sea-cliff facing Mano-bay, about 250 m. SE of the primary school, Sawane-machi, Sado-gun, Niigata-ken. TM Kawarada, Lat. 37°59′N, Long. 138°17′E]. Sawane formation, Pliocene, Cushman and Ozawa, 1928b.

Loc. G-1: [Osawa-quarry, Okambara-mura, Nakakambara-gun, Niigata-ken, TM Niitsu, Lat. 37°41′N, Long. 139°6′E]. Osawa formation, Pliocene, Oinomikado, 1941a.

Loc. G-2: [Valley-cliff, immediately S of Sakaya, Sakaya-mura, Santo-gun, Niigata-ken. TM Izumozaki, Lat. 37°35′N, Long. 138°45′E]. Natsukawa formation, Pliocene, Matsui and Nakagawa, 1942.

Loc. G-3: [Roadside cutting, 200 m. E of Kutta, Santo-gun, Niigata-ken. TM Izumozaki. Lat. 37°34′N, Long. 138°44′E]. Natsukawa formation, Pliocene, Yabe and Hanzawa, 1923.

Loc. G-4: [Boring core at Shimotaka-machi, Arakawa-mura, Kariha-gun, Niigata-ken. TM Kashiwazaki, Lat. 37°25′N, Long. 138°36′E]. Natsukawa formation, Pliocene, K. Asano, 1938a.

Loc. G-5: [Valley-cliff of Natsukawa-dani, 1 km. E of Kabazaki, Kitajomura, Kariha-gun, Niigata-ken. TM Kashiwazaki, Lat. 37°23′N, Long. 138°37′E]. Natsukawa formation, Pliocene, K. Asano, 1938a.

Loc. G-6: [No. 1 of boring core at Kamitajiri, Tajiri-mura, Kariha-gun, Niigata-ken. TM Kashiwazaki, Lat. 37°21′N, Long. 138°34′24″E]. Haizume and Nishiyama formations, Pliocene, Husezima and Maruhasi, 1944.

Loc. G-7: [No. 2 of boring core, ibid. TM Kashiwazaki, Lat. 37°21′30″N, Long. 138°34′57″E]. Haizume and Nishiyama formations, Pliocene, Husezima and Maruhasi, 1944.

Loc. G-8: [No. 4 of boring core, ibid. TM Kashiwazaki, Lat. 37°21′27″N, Long. 138°35′30″E]. Haizume and Nishiyama formations, Pliocene, Husezima and Maruhasi, 1944.

Loc. G-9: [No. 5 of boring core, ibid. TM Kashiwazaki, Lat. 37°21′2″N, Long. 138°36′3″E]. Haizume and Nishiyama formations, Pliocene, Husezima and Maruhasi. 1944.

Loc. N: [River-cliff of the Saikawa, near the large sandbank, about 400 m. SE of Onma, Sakiura-mura, Ishikawa-gun, Ishikawa-ken. TM Kanazawa, Lat. 36°31′N, Long. 136°41′E]. Onma formation, Pliocene, Cushman and Ozawa, 1928b.

Loc. I-1: [Roadside cutting near the temple Manpukuji, Kakio-mura, Tsuzuki-gun, Kanagawa-ken. TM Southwestern part of Tokyo, Lat. 35°36′N, Long. 139°30′E]. Kakio formation, Pliocene, Y. Otsuka, 1932.

Loc. I-2: [Roadside cutting near Yamaguchi, Kawasaki City. TM Southwestern part of Tokyo, Lat. 35°36′N, Long. 139°30′E]. Kakio formation, Pliocene, K. Asano, 1944.

Loc. I-3: [300 m. N of Hitodo, Kyowa-mura, Ashigara-kami-gun, Kanagawa-ken. TM Hadano, Lat. 35°23′N, Long. 139°04′E]. Misaka, Miocene, Hanzawa, 1931a.

Loc. J-1: [Roadside cutting, 100 m. N of Mimata, Fusamoto-mura, Isumi-gun, Chiba-ken. TM Otaki, Lat. 35°15′N, Long. 140°15′E]. Kiwada formation, "Pliocene," K. Asano, 1938a. [Miocene].

Loc. J-2: [Roadside cutting about 100 m. N of Seki, Sekitoyo-mura, Kimitsu-gun, Chiba-ken. TM Futtsu, Lat. 35°12′ N, Long. 139°59′E]. Kiwada formation, "Pliocene," K. Asano, 1938a. [Miocene].

Loc. J-3: [Roadside cutting about 100 m. N of Hirose, Kokubu-mura, Awa-gun, Chiba-ken. TM Nago, Lat. 35°10′N, Long. 139°55′E]. Kiwada formation, "Pliocene," K. Asano, 1938a. [Miocene].

Loc. J-4: [Roadside cutting on main road, about 200 m. SW of Kamo. Toyota-mura, Awa-gun, Chiba-ken. TM Nago, Lat. 35°N, Long. 139°58′E]. Kiwada formation, "Pliocene," K. Asano, 1938a. [Miocene].

Loc. K-1: [Roadside cutting, Oshikiri, Hongo-mura, Kamakura-gun, Kanagawa-ken. TM Yokohama, Lat. 35°23′N, Long. 139°33′E]. Kanazawa "series," "Pliocene," K. Asano, 1938a.

Loc. K-2: [Roadside cutting, immediately W of Nishinotani, Hongo-mura, Kamakura-gun, Kanagawa-ken. TM Yokohama, Lat. 35°23′N, Long. 139°32′E]. Koshiba "series," "Pliocene," K. Asano, 1938a.

Loc. K-3: [Roadside cutting, about 50 m. E of Uchikoshi-dani, Toyota-mura, Kamakura-gun, Kanagawa-ken. TM Yokohama, Lat. 35°23′ N, Long. 139°32′E]. Naganuma formation, Pliocene, K. Asano, 1936b.

Loc. K-4: [Roadside cutting at Yatsu, Kanagawa-machi, Kanagawa-ken. TM Yokohama, Lat. 35°21′N, Long. 139°37′E]. Kanazawa "series," "Pliocene," K. Asano, 1938a.

Loc. K-5: [Roadside cutting at Ueki, Tamanawa-mura, Kamakura-gun, Kanagawa-ken. TM Yokohama, Lat. 25°20′N, Long. 139°30′E]. Kanazawa "series," "Pliocene," K. Asano, 1938a.

Loc. K-6: [Roadside cutting, immediately S of Sakashita, Tamanawa-mura, Kamakura-gun, Kanagawa-ken. TM Yokohama, Lat. 35°20′N, Long. 139°30′E]. Kanazawa "series," "Pliocene," K. Asano, 1938a.

Loc. K-7: [Roadside cutting between Takaya and Watanai, Muraoka-mura, Kamakura-gun, Kanagawa-ken. TM Yokohama, Lat. 35°20′N, Long. 139°30′E]. Tomioka formation (below unconformity), Pliocene, K. Asano, 1936b.

Loc. K-8: [Roadside cutting opposite Nojima-ura, Kanagawa-machi, Kanagawa-ken. TM Gokurakuji, Lat. 35°20′N, Long. 139°39′E]. Kanazawa "series," "Pliocene," K. Asano, 1938a.

Loc. K-9: [Roadside cutting about 500 m. NE of Shimomiyata, Hatsuse-mura, Miura-gun, Kanagawa-ken. TM Gokurakuji, Lat. 35°11′N, Long. 139°39′E]. Hatsuse formation, Pliocene, K. Asano, 1938a.

Loc. K-10: [Roadside cutting about 300 m. NW of Kamimiyata, Minamishita-ura-mura, Miura-gun, Kanagawa-ken. TM Gokurakuji, Lat. 35°11′N, Long. 139°40′E]. Hatsuse formation, Pliocene, K. Asano, 1938a.

Loc. L-1: [Roadside cutting, about 100 m. N of Dainichi, Ugari-mura, Suchi-gun, Shizuoka-ken. TM Mitsuke, Lat. 34°49′N, Long. 139°55′E]. Dainichi formation, Pliocene, K. Asano, 1938a.

Loc. L-2: [800 m. E of Asuka, Taruki-mura, Ogasa-gun, Shizuoka-ken. TM Mitsuke, Lat. 34°48′N, Long. 138°E]. Dainichi formation, Pliocene, K. Asano, 1938a.

Loc. L-3: [Roadside cutting between Hosoya and Tombe, Haranotani-mura, Ogasa-gun, Shizuoka-ken. TM Mitsuke, Lat. 34°48′N, Long. 137°57′E]. Hosoya formation. Pliocene, K. Asano, 1938a.

Loc. L-4: [Roadside cutting, 100 m. E of Kamiyashiki, Taruki-mura, Ogasa-gun, Shizuoka-ken. TM Kakegawa, Lat. 34°48′N, Long. 138°E]. Dainichi formation, Pliocene, K. Asano, 1938a.

Loc. L-5: [Tunnel of Sugiya, Nango-mura, Ogasa-gun, Shizuoka-ken. TM Kakegawa, Lat. 34°42′N, Long. 138°2′E]. Nango formation, Pliocene, K. Asano, 1938a.

Loc. L-6: [Roadside cutting at Shimomata, 1 km. S of Kakegawa-machi, Ogasa-gun, Shizuoka-ken. TM Kakegawa, Lat. 34°46′N, Long. 138°1′E]. Kechienji formation, Pliocene, Ishizaki, 1943b.

Loc. L-7: [Roadside cutting about 200 m. S of Kechienji, Nango-mura, Ogasa-gun, Shizuoka-ken. TM Kakegawa, Lat. 34°46′N, Long. 138°2′E]. Kechienji formation, Pliocene, K. Asano, 1938a.

Loc. L-8: [800 m. S of Funakoshi, Shimizu-shi, Shizuoka-ken. TM Shizuoka, Lat. 35°N, Long. 138°28′E]. Negoya formation, Pliocene, K. Asano, 1938a.

Loc. L-6: [Shimo-shiraiwa, Shimo-omi-mura, Tagata-gun, Shizuoka-ken. TM Shuzenji, Lat. 34°58′N, Long. 138°59′E]. Shimoshiroiwa formation, Miocene, Hanzawa, 1931b.

Loc. M-1: [River cliff about 200 m. N of the shrine, at Ioki, Ioki-mura, Aki-gun, Kochi-ken. TM Aki, Lat. 33°29′N, Long. 133°56′E]. Konomine formation, Pliocene, K. Asano, 1936d.

Loc. M-2: [Riverside cutting, a short distance E of Todani, N of Tonohama, Yasuda-machi, Aki-gun, Kochi-ken. TM Aki, Lat. 33°27′N, Long. 133°58′E]. Konomine formation, Pliocene, K. Asano, 1936d.

Loc. M-3: [Northern slope of the hill near the boundary of Yasuda-mura and Tano-machi, Aki-gun, Kochi-ken. TM Aki, Lat. 33°26′N, Long. 134°E]. Konomine formation, Pliocene, K. Asano, 1936d.

Loc. N: [Northern cliff of the Komaru-gawa, W of Hagenoshita, Uwae-mura, Koyu-gun Miyazaki-ken. TM Takanabe, Lat. 32°9′N Long. 131°31′E]. Koonji formation, Pliocene, Oinomikado, 1941b.

Loc. O-1: [Roadside cutting, about 500 m. N of Yumoto Railway Station, Yumoto-machi, Ishiki-gun, Fukushima-ken. TM Taira, Lat. 37°N, Long. 140°51′E]. Asagai formation, Oligocene, K. Asano, 1949b.

Loc. O-2: [Roadside cutting at northern entrance of Kokozura, Nakosomachi, Ishiki-gun, Fukushima-ken, TM Onahama, Lat. 36°51′N, Long. 140°47′E]. Kokozura formation, Miocene, K. Asano, 1949a.

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Entries are arranged alphabetically and each entry carries the following information in this order: generic and specific name, author, date; bibliographic references; formation and age; locality in condensed form; repository; remarks. Interpolations in the list by the compiler are enclosed in square brackets. These include comments and corrections of previous errors. Abbreviations for the repositories are as follows:

CL: Cushman Laboratory for Foraminiferal Research.

GF: Geological Institute, Kyushu University, Fukuoka.

GK: Geological Institute, Kyoto University.

GS: Institute of Geology and Paleontology, Tohoku University, Sendai.

GT: Geological Institute, Tokyo University.

GW: Geological Institute, National Taiwan University.
NM: United States National Museum.
NR: Research Institute for Natural Resources, Tokyo.

Ammobaculites yumotoensis Asano, 1949b, p. 474, fig. 1–1a, b. Asagai, Oligocene. Loc. O-1. Holotype, GS, No. 67029.

Angulogerina ikebei Husezima and Maruhasi, 1944, p. 396, pl. 34, figs. 8a–c. Haizume, Pliocene. Loc. G-6. Holotype, NR.

—— *kokozuraensis* Asano, 1949a, p. 428, fig. 1–50–53. Kokozura, Miocene. Loc. O-2. Holotype and paratypes, GS. No. 67040.

Anomalina floscularia Yokoyama, 1890, p. 194, pl. 24, fig. 19. Poronai, [Oligocene]. Loc. B. Repository unknown.

Astacolus etigoensis Asano, 1938a, p. 207, pl. 29, fig. 23. Natsukawa, Pliocene. Loc. G-5. Holotype, GS, No. 21472.

Astrononion stelligerum (d'Orbigny). [*Nonionina*]. Asano, 1938d, p. 598, pl. 15, figs. 9a, b. Naganuma, Pliocene. Loc. K-7. Hypotype, GS.

Baggina totomiensis Makiyama, 1931, p. 52, text-fig. 4. [Dainichi, Pliocene. Loc. L-2]. Holotype, GK.

Bolivina euplectella Yokoyama, 1890, p. 191, pl. 14, figs. 13, 14. Poronai [Oligocene]. Loc. B. Repository unknown.

—— *hantkeniana* Brady. Asano, 1938e, p. 601, pl. 16, fig. 15. Konomine, Pliocene. Loc. M-1. Hypotype, GS.

—— *hanzawai* Asano, 1936e, p. 330, pl. 37, figs. 9a, b. Dainichi, Pliocene. Loc. L-2. Holotype, GS., No. 21383.

—— *hanzawai* Asano. Asano, 1938e, p. 602, pl. 16, fig. 8. Konomine, Pliocene. Loc. M-1. Hypotype, GS. Also pl. 16, fig. 13. Hosoya, Pliocene. Loc. L-3, Hypotype, GS.

—— *robusta* Brady. Asano, 1938e, p. 601, pl. 16, figs. 5a, b. Hosoya, Pliocene. Loc. L-3. Hypotype, GS.

—— *seminuda* Cushman. Asano, 1938e, p. 602, pl. 16, fig. 10. Naganuma, Pliocene. Loc. K-7. Hypotype, GS.

—— *subangularis ogasaensis* Asano, 1936e, p. 331, pl. 37, fig. 8. Hosoya, Pliocene. Loc. L-3. Holotype, GS, No. 21384.

—— —— —— Asano. Asano, 1938e, p. 602, pl. 16, fig. 16. Hosoya, Pliocene. Loc. L-3. Topotype, GS.

Bolivinita quadrilatera cuneata Asano, 1938e, p. 608, pl. 16, figs. 19a, b. Naganuma, Pliocene. Loc. K-7. Holotype, GS, No. 21427.

Bulimina baccata Yokoyama, 1890, p. 190, pl. 24, fig. 9. Poronai, [Oligocene]. Loc. B. Repository unknown.

—— *capitata* Yokoyama, 1890, p. 190, pl. 24, fig. 10. Poronai, [Oligocene]. Loc. B. Repository unknown.

—— *ezoensis* Yokoyama, 1890, p. 190, pl. 24, fig. 5. Poronai, [Oligocene]. Loc. B. Repository unknown.

—— *polymorphinoides* Yokoyama, 1890, p. 191, pl. 24, fig. 11. Poronai, [Oligocene]. Loc. B. Repository unknown.

—— *schwageri* Yokoyama, 1890, p. 190, pl. 24, figs. 6–8. Poronai, [Oligocene]. Loc. B. Repository unknown.

Buliminella hanzawai Asano, 1949a, p. 428, fig. 1–54, 55. Kokozura, Miocene. Loc. O-2. Holotype, GS, No. 67048.

Cassidulina japonica Asano and Nakamura, 1937, p. 144, pl. 13, fig. 2. Sawane, Pliocene. Loc. F. Holotype, GS, No. 21434.

—— *kasiwazakiensis* Husezima and Maruhasi, 1944, p. 399, pl. 34, figs. 13a–c. Haizume, Pliocene. Loc. G-6. Holotype, NR. [*Cassidulina yabei* Asano and Nakamura].

—— *kazusaensis* Asano and Nakamura, 1937, p. 146, pl. 14, figs. 2a, b. Kiwada, [Miocene]. Loc. J-1. Holotype, GS, No. 21438.

—— *laevigata* d'Orbigny. Asano and Nakamura, 1937, p. 149, pl. 13, figs. 4a, b. Kanazawa, Pliocene. Loc. K-4. Hypotype, GS.

—— *orientale* Cushman. Asano and Nakamura, 1937, p. 147, pl. 14, figs. 6a–c. Hatsuse, Pliocene. Loc. K-10. Hypotypes, GS.

—— *sagamiensis* Asano and Nakamura, 1937, p. 147, pl. 14, figs. 5a–c. Hatsuse, Pliocene. Loc. K-10. Holotype, GS, No. 21439.

—— *setanaensis* Asano and Nakamura, 1937, p. 145, pl. 13, figs. 7a, b. Setana, Pliocene. Loc. C-7. Holotype, GS, No. 21437.

—— *subglobosa* Brady. Asano and Nakamura, 1937, p. 147, pl. 13, figs. 3a, b. Kanazawa, Pliocene. Loc. K-1. Hypotype, GS.

—— —— *parva* Asano and Nakamura, 1937, p. 148, pl. 13, figs. 5a, b. Kanazawa, Pliocene. Loc. K-8. Holotype, GS, No. 21140.

—— *sublimbata* Asano and Nakamura, 1937, p. 146, pl. 14, fig. 3. Sawane, Pliocene. Loc. F. Holotype, GS, No. 21436.

—— *yabei* Asano and Nakamura, 1937, p. 145, pl. 14, figs. 1a, b. Setana, Pliocene. Loc. C-4. Holotype, GS, No. 21435.

Ceratobulimina hanzawai Asano, 1949a, p. 428, fig. *1*—23–27. Kokozura, Miocene. Loc. O-2. Holotype and paratypes, GS, No. 67046.

Cibicides cf. *lobatulus* (Walker and Jacob). [*Nautilus*]. Asano, 1949b, p. 476, fig. *2*—7a, b. Asagai, Oligocene. Loc. O-1. Hypotype, GS, No. 67037.

—— sp. Asano, 1949b, p. 478, fig. *2*—6a–c. Asagai, Oligocene. Hypotype, GS, No. 67014.

Clavulina tokaiensis Asano, 1936e, p. 326, pl. 36. figs. 3, 4. Hosoya, Pliocene, Loc. L-3. Holotype, GS, No. 21332.

—— *tosaensis* Asano, 1936d, p. 944, pl. 52, figs. 2, 3. Konomine, Pliocene. Loc. M-2. Holotype, GS, No. 21391.

—— *yabei* Asano, 1936c, p. 612, pl. 30, figs. 2–4. Tomioka, Pliocene. Loc. K-7. Holotype, GS, No. 21363.

—— —— *akiensis* Asano, 1936d, p. 944, pl. 52, figs. 4, 5. Konomine, Pliocene. Loc. M-2. Holotype, GS, No. 21390.

"*Cristellaria*" *peregrina* Schwager. Asano, 1938a, p. 251, pl. 29, figs. 6, 7. Konomine. Pliocene. Loc. M-3. Hypotype, GS. [*Planularia*]. Also, pl. 29, fig. 11, Konomine, Pliocene. Loc. M-1. Hypotype, GS. [*Planularia*].

Cruciloculina japonica Asano, 1949c, p. 480, pl.

80, fig. 10, Sawane, Pliocene. Loc. F. Holotype, GS, No. 67015. Also pl. 80, figs. 1, 2, 6, Sawane, Pliocene. Loc. F. Paratypes, GS. Also pl. 80, figs. 7–9, 11–13, Setana, Pliocene. Loc. C-4. Paratype, GS.

Cyclammina sp. Asano, 1949b, p. 474, fig. *1*—5, 6. Asagai, Oligocene. Loc. O-1. Hypotype, GS, No. 67031.

Dentalina communis d'Orbigny. Asano, 1938a, p. 213, pl. 25, fig. 32. Hosoya, Pliocene, Loc. L-3. Hypotype, GS. Also pl. 27, fig. 50. Tomioka, Pliocene. Loc. K-7. Hypotype, GS.

—— *emaciata* Reuss, Asano, 1938a, p. 213, pl. 25, fig. 13. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 25, figs. 20, 21, 23. Kechienji, Pliocene. Loc. L-7. Hypotype, GS. Also pl. 27, fig. 19. Kiwada, [Miocene]. Loc. J-4. Hypotype, GS. Also pl. 28, fig. 21. Kanazawa, Pliocene. Loc. K-6. Hypotype, GS. Also pl. 28, fig. 24. Kanazawa, Pliocene. Loc. K-5. Hypotype, GS. Also pl. 28, fig. 28. Kanazawa, Pliocene. Loc. K-8. Hypotype, GS. Also pl. 29, fig. 14. Konomine, Pliocene. Loc. M-2. Hypotype, GS. Also pl. 29, fig. 24. Konomine, Pliocene. Loc. M-3. Hypotype, GS.

—— *farcimen* (Soldani). [*Orthoceras*]. Asano, 1938a, p. 214, pl. 25, fig. 18. Hosoya, Pliocene. Loc. L-3. Hypotype, GS.

—— *filiformis* (d'Orbigny). [*Nodosaria*]. Asano, 1938a, p. 214, pl. 27, fig. 22. Kiwada, [Miocene] Loc. J-3. Hypotype, GS. Also pl. 27, fig. 47. Tomioka, Pliocene. Loc. K-7. Hypotype, GS.

——*mucronata* Neugeboren. Asano, 1938a, p. 213, pl. 25, fig. 33. Hosoya, Pliocene. Loc. L-3. Hypotype, GS.

—— *nakamurai* Asano, 1938a, p. 214, pl. 27, fig. 54. Koshiba, Pliocene. Loc. K-2. Holotype, No. 21481. Also pl. 27, fig. 55. Naganuma, Pliocene. Loc. K-3. Paratype, GS.

—— *roemeri* Neugeboren. Asano, 1938a, p. 214, pl. 27, figs. 5, 6. Tomioka, Pliocene. Loc. K-7. Hypotype, GS.

——*setanaensis* Asano, 1938a, p. 215, pl. 30, fig. 9. Setana, Pliocene. Loc. C-5. Paratype, GS. Also pl. 30, fig. 10. Setana, Pliocene. Loc. C-8. Holotype, GS, No. 21482. Also pl. 30, figs. 11, 12. Setana, Pliocene. Loc. C-6. Paratype, GS. Also pl. 30, figs. 30–32. Natsukawa. Pliocene. Loc. G-4. Paratype, GS.

—— *siribesiensis* Asano, 1938a, p. 215, pl. 30, figs. 15, 16. Setana, Pliocene. Loc. C-1. Holotype, GS. No. 21438.

—— *soluta* Reuss. Asano, 1938a, p. 213, pl. 25, fig. 31, Hosoya, Pliocene. Loc. L-3. Hypotype, GS.

—— *yabei* Asano, 1936e, p. 329, pl. 36, figs. 10–12. Kechienji, Pliocene, Loc. L-7. Holotype, GS, No. 21380.

—— *yabei* Asano. Asano, 1938a, p. 213, pl. 25, fig. 17. Kechienji, Pliocene. Loc. L-7. Topotype, GS. Also pl. 29, fig. 32. Natsukawa, Pliocene. Loc. G-4. Hypotype, GS.

Discorbis nipponica Husezima and Maruhasi, 1944, p. 397, pl. 34, figs. 9a–c. Haizume, Pliocene. Loc. G-8. Holotype, NR.

Dyofrondicularia nipponica Asano, 1936e, p. 330, pl. 37, figs. 2a, b. Kechienji, Pliocene. Loc. L-7. Holotype, GS, No. 21382. Also, fig. repeated; Asano, 1938a, p. 189, pl. 24, fig. 16.

Ellipsonodosaria hayasakai Ishizaki, 1943c, p. p. 683, text-figs. 2a, b. Konomine, Pliocene. Loc. M-3. Holotype, GW.

—— *hyugaensis* Ishizaki, 1943c, p. 686, text-figs. 12, 13a, b. Koonji, Pliocene. Loc. N. Holotype, GW.

—— *japonica* Ishizaki, 1943c, p. 682, text-figs. 14a, b; 15. Koonji, Pliocene. Loc. N. Holotype, GW.

—— *ketienziensis* Ishizaki, 1943c, p. 684, text-figs. 1, 6, 11a, b. Kechienji, Pliocene. Holotype, GW.

—— *lepidula* (Schwager). [*Nodosaria*]. Ishizaki, 1943c, p. 680, text-figs. 3a, b; 4. Koonji, Pliocene. Loc. N. Hypotype, GW.

—— *oinomikadoi* Ishizaki, 1943c, p. 685, text-figs. 7a, b; 8–10. Koonji, Pliocene. Loc. N. Holotype, GW.

Elphidiella nagaoi Asano, 1938c, p. 590, pl. 14, figs. 8a, b. Setana, Pliocene. Loc. C-5. Holotype, GS, No. 21421.

Elphidium advenum (Cushman). [*Polystomella*]. Asano, 1938c, p. 587, pl. 43, figs. 3a, b. Setana, Pliocene. Loc. C-2. Hypotype, GS.

—— *asagaiense* Asano, 1949b, p. 476, fig. *2*—1a, b. Asagai, Oligocene. Loc. O-1. Holotype, GS, No. 67043. Also fig. *2*–2. Asagai, Oligocene. Loc. O-1. Paratype, GS.

—— *craticulatum* (Fichtel and Moll). [*Nautilus*]. Asano, 1938c, p. 588, pl. 14, figs. 6a, b. Naganuma, Pliocene. Loc. K-7. Hypotype, GS.

—— *crispum* (Linné). [*Nautilus*]. Asano, 1938c, p. 585, pl. 14, figs. 1a, b. Setana, Pliocene. Loc. C-4. Hypotype, GS.

—— *etigoense* Husezima and Maruhasi, 1944, p. 392, pl. 34, figs. 1a, b. Haizume, Pliocene. Loc. G-7. Holotype, NR.

—— *ezoense* Asano, 1937b, p. 787, pl. 24, figs. 1, 2; text-fig. 1. Takikawa, Pliocene. Loc. A. Holotype, GS, No. 21433. [*Cribroelphidium*]. Also, fig. repeated; Asano, 1938c, p. 589, pl. 14, fig. 11.

—— cf. *fabum* (Fichtel and Moll). [*Nautilus*]. Asano, 1938c, p. 587, pl. 14, figs. 7a, b. Setana, Pliocene. Loc. C-2. Hypotype, GS. [*Elphidium etigoense* Husezima and Maruhasi].

—— *hanzawai* Asano, 1939, p. 426. text-figs. 3, 4a, b. Shibikawa, Pliocene. Loc. D. Holotype, GS, No. 62910.

—— *jenseni* (Cushman). [*Polystomella*]. Asano, 1938c, p. 588, pl. 4, figs. 5a, b. Setana, Pliocene. Loc. C-2. Hypotype, GS.

—— *planum* Husezima and Maruhasi, 1944, p. 392, pl. 34, figs. 2a, b. Haizume, Pliocene. Loc. G-6. Holotype, NR. [*Elphidium subgranulosum* Asano].

—— *rarum* Husezima and Maruhasi, 1944, p. 393, pl. 34, figs. 3a, b. Haizume, Pliocene. Loc. G-9. Holotype, NR. [*Elphidium advenum* (Cushman)].

—— *subgranulosum* Asano, 1938c, p. 586, pl. 43, figs. 4a, b. Setana, Pliocene. Loc. C-2. Holotype, GS, No. 21418.

—— *suzukii* Husezima and Maruhasi, 1944, p. 394, pl. 34, figs., 4a, b. Haizume, Pliocene. Loc.

G-7. Holotype, NR. [*Elphidium advenum* (Cushman)].

—— *yabei* Asano, 1938c, p. 589, pl. 14, figs. 9a, b; 10a, b. Setana, Pliocene. Loc. C-5. Holotype, GS, No. 21419. [*Cribroelphidium*].

—— *yumotoense* Asano, 1949b, p. 476, fig. *1*—7a, b. Asagai, Oligocene. Loc. O-1. Holotype, GS, No. 67035. Also fig. *1*–8, 9. Asagai, Oligocene. Loc. O-1. Paratype, GS.

Epistominella pulchella Husezima and Maruhasi, 1944, p. 398, pl. 34, figs. 10a–c. Haizume, Pliocene. Loc. G-6. Holotype, NR. [*Pseudoparrella*]

Eponides niigataensis Husezima and Maruhasi, 1944, p. 398, pl. 34, figs. 11a–c. Haizume, Pliocene. Loc. G-7. Holotype, NR.

—— *rotundus* Husezima and Maruhasi, 1944, p. 399, pl. 34, figs. 12 a–c. Nishiyama, Pliocene. Loc. G-9. Holotype, NR.

—— *sasai* Asano, 1938b, p. 94, pl. 10, figs. 2a–c; 3a, b. Setana, Pliocene. Loc. C-7. Holotype, GS, No. 21431.

Faujasina (?) sp. Asano, 1949b, p. 476, fig. *2*—5a–c. Asagai, Oligocene. Loc. O-1. Hypotype, GS, No. 67036.

Fissurina circulo-costa Asano, 1938a, p. 219, pl. 30, fig. 17. Setana, Pliocene. Loc. C-6. Holotype, GS, No. 21484. [*Entosolenia*].

—— *orbignyana* Seguenza. Asano, 1938a, p. 218, pl. 27, fig. 51. Tomioka, Pliocene. Loc. K-7. Hypotype, GS. [*Entosolenia*]. Also pl. 30, fig. 22. Setana, Pliocene. Loc. C-6. Hypotype, GS. [*Entosolenia*].

—— —— *lacunata* (Burrows and Holland). [*Lagena*]. Asano, 1938a, p. 219, pl. 27, figs. 27, 28. Tomioka, Pliocene. Loc. K-7. Hypotype. GS. [*Entosolenia*].

Frondicularia advena Cushman. Asano, 1938a, p. 188, pl. 24, fig. 17, Kechienji, Pliocene. Loc. L-7. Hypotype, GS.

—— *foliacea* Schwager. Asano, 1938a, p. 188, pl. 28, fig. 16. Kanazawa, Pliocene. Loc. K-4. Hypotype, GS.

—— *nangoensis* Asano, 1936e, p. 329, fig. 5. Kechienji, Pliocene. Loc. L-7. Holotype, GS, No. 21381. Also, fig. repeated; Asano, 1938a, p. 189, pl. 24, fig. 18.

—— *scolopensraria* Yokoyama, 1890, p. 188, pl. 24, fig. 3. Poronai, [Oligocene]. Loc. B. Repository unknown.

Gaudryina (*Pseudogaudryina*) *oga* Asano, 1939, p. 425, text-figs. 2a–c. Shibikawa, Pliocene. Loc. D. Holotype, GS, No. 62912.

—— *ogasaensis* Asano, 1936e, p. 326, pl. 36, figs. 2a, b. Hosoya, Pliocene. Loc. L-3. Holotype, GS, No. 21331.

—— *yabei* Asano, 1939, p. 425, text-figs. 1a–c. Shibikawa, Pliocene. Loc. C-2. Holotype, GS, No. 62911.

Guttulina austriaca d'Orbigny. Asano, 1938b, p. 94, pl. 11, fig. 3. Setana, Pliocene. Loc. C-2. Hypotype, GS.

—— *irregularis* var. *nipponensis* Cushman and Ozawa, 1930, p. 27, pl. 7, figs. 3a–c. Onma, Pliocene. Loc. G-3. Holotype, CL, No. 11140.

—— *kishinouyi* Cushman and Ozawa, 1930, p. 40, pl. 8, figs. 5, 6. Natsukawa, Pliocene. Loc. G-3. Holotype, CL, No. 11234.

—— aff. *lactaea* Walker and Jacob. Cushman and Ozawa, 1928b, p. 67, pl. 14, figs. 4, 5. Sawane, Pliocene. Loc. F. Hypotype, GT.

—— *orientalis* Cushman and Ozawa, 1928a, p. 15, pl. 2, fig. 1. Sawane, Pliocene. Loc. F. Holotype, GT.

—— —— Cushman and Ozawa. Cushman and Ozawa, 1928b, p. 66, pl. 13, fig. 1; pl. 14, figs. 1, 2. Sawane, Pliocene. Loc. F. Topotype, GT.

—— —— Cushman and Ozawa. Cushman and Ozawa, 1930, p. 24, pl. 3, figs. 2, 3. Sawane, Pliocene. Loc. F. Topotype, GT.

—— *sadoensis* (Cushman and Ozawa). [*Sigmomorpha*]. Cushman and Ozawa. 1930, p. 49, pl. 37, figs. 1, 2. Sawane, Pliocene. Loc. F. Topotype, GT.

—— —— (Cushman and Ozawa). [*Sigmomorpha*]. Asano, 1938b, p. 95, pl. 11, fig. 7. Setana, Pliocene. Loc. C-3. Hypotype, GS.

—— *spicaeformis* (Roemer). [*Polymorphina*]. Cushman and Ozawa, 1928b, p. 68, pl. 14, figs. 8, 9. Onma, Pliocene. Loc. H. Hypotype, GT.

—— *yabei* Cushman and Ozawa, 1928b, p. 67, pl. 13, fig. 2; pl. 14, fig. 6. Sawane, Pliocene. Loc. F. Holotype, GT.

—— —— Cushman and Ozawa. Cushman and Ozawa, 1930, p. 30, pl. 4, figs. 6, 7. Sawane, Pliocene. Loc. F. Topotype, GT.

—— —— Cushman and Ozawa. Asano, 1938b, p. 95, pl. 11, fig. 8. Setana, Pliocene. Loc. C-3. Hypotype, GS.

—— —— var. *ovale* Cushman and Ozawa, 1928b, p. 68, pl. 13, fig. 3; pl. 14, fig. 7, Sawane, Pliocene. Loc. F. Holotype, GT.

—— —— —— —— Cushman and Ozawa. Cushman and Ozawa, 1930, p. 31, pl. 40, fig. 6. Sawane, Pliocene. Loc. F. Topotype, GT.

—— *yamazakii* Cushman and Ozawa, 1930, p. 40, pl. 6, fig. 3. Natsukawa, Pliocene. Loc. G-3. Paratype, NM.

Hanzawaia nipponica Asano, 1944, p. 97, pl. 4, figs. 1, 2. Kakio, Pliocene. Loc. I-2. Holotype, GS, No. 66016.

—— *tagaensis* Asano, 1949a, p. 430, fig. *2*—28–32. Kokozura, Miocene. Holotype and paratypes, GS, No. 67047.

Karreriella baccata japonica Asano, 1938b, p. 90, pl. 10, figs. 1a–c. Setana, Pliocene. Loc. C-7. Holotype, GS, No. 21448.

Lagena acuticosta Reuss. Asano, 1938a, p. 217, pl. 27, fig. 25. Kiwada, [Miocene]. Loc. J-3. Hypotype, GS. Also pl. 27, fig. 36. Tomioka, Pliocene. Loc. J-3. Hypotype, GS. Also pl. 29, fig. 26. Konomine, Pliocene. Loc. M-2. Hypotype, GS. Also pl. 30, fig. 19, Setana, Pliocene. Loc. C-7. Hypotype, GS.

—— *elongata* (Ehrenberg). [*Miliola*]. Asano, 1938a, p. 217, pl. 27, figs. 37, 59. Tomioka, Pliocene. Loc. K-7. Hypotype, GS.

—— *clavata* (d'Orbigny). [*Oolina*]. Asano, 1938a, p. 216, pl. 27, figs. 56, 61. Tomioka, Pliocene. Loc. K-7. Hypotype, GS. Also pl. 30, fig. 26. Natsukawa, Pliocene. Loc. G-4. Hypotype, GS.

—— *globosa* (Montagu). [*Serpula*]. Asano, 1938a, p. 215, pl. 27, fig. 52. Tomioka, Pliocene. Loc. K-7. Hypotype, GS.

—— *gottschi* Yokoyama, 1890, p. 188, pl. 24, fig. 1. Poronai, [Oligocene]. Loc. B. Repository unknown.
—— *gracilis* Williamson. Asano, 1938a, p. 216, pl. 27, fig. 45. Tomioka, Pliocene. Loc. K-7. Hypotype, GS. Also pl. 30, fig. 21, Setana, Pliocene. Loc. C-6. Hypotype, GS.
—— *hexagona* (Williamson). [*Entosolenia*]. Asano, 1938a, p. 216, pl. 27, figs. 38, 39. Tomioka, Pliocene. Loc. K-7. Hypotype, GS. [*Entosolenia*]. Also pl. 29, fig. 27. Konomine, Pliocene. Loc. M-2. Hypotype, GS.
—— *hispida* Reuss. Asano, 1938a, p. 216, pl. 27, fig. 53. Tomioka, Pliocene. Loc. K-7. Hypotype, GS.
—— *hyugaensis* Oinomikado, 1941b, p. 518, text-fig. 2. Koonji, Pliocene. Loc. N. Holotype, GF. [*Lagenonodosaria*].
—— *semistriata* Williamson. Asano, 1938a, p. 217, pl. 25, fig. 25. Kechienji, Pliocene. Loc. L-7. Hypotype, GS. Also pl. 27, fig. 44. Tomioka, Pliocene, Loc. K-7. Hypotype, GS. Also pl. 29, fig. 29. Konomine, Pliocene. Loc. M-2. Hypotype, GS. Also pl. 30, fig. 25. Natsukawa, Pliocene. Loc. G-4. Hypotype, GS.
—— *squamosa* (Montagu) [*Vermiculum*]. Asano, 1938a, p. 216, pl. 27, figs. 40, 41. Tomioka, Pliocene. Loc. K-7. Hypotype, GS. [*Entosolenia*]. Also pl. 29, fig. 31. Natsukawa, Pliocene. Loc. G-4. Hypotype, GS.
—— *striata* (d'Orbigny). [*Oolina*]. Asano, 1938a, p. 217, pl. 29, fig. 28. Konomine, Pliocene. Loc. M-2. Hypotype, GS.
—— —— *strumosa* Reuss. Asano, 1938a, p. 217, pl. 25, fig. 22. Kechienji, Pliocene. Loc. L-7. Hypotype, GS. Also pl. 27, fig. 44. Tomioka, Pliocene. Loc. K-7. Hypotype, GS.
—— *substriata* Williamson. Asano, 1938a, p. 216, pl. 27, fig. 35. Tomioka, Pliocene. Loc. K-7. Hypotype, GS.
Lagenonodosaria fukushimaensis Asano, 1949a, p. 426, fig. *1*—4–11; 20, 21 Kokozura, Miocene. Loc. O-2. Holotype and paratypes, GS, No. 67042.
—— *hirsuta* (d'Orbigny). [*Nodosaria*]. Ishizaki, 1943b, p. 217, pl. 10, fig. 4. Konomine, Pliocene. Loc. M-2. Hypotype, GW.
—— *hyugaensis* (Oinomikado). [*Nodosaria*]. Ishizaki, 1943b, p. 217, pl. 10, figs. 1–2; 6. Koonji, Pliocene. Loc. N. Topotype, GW.
—— *sagamiensis* Asano. Ishizaki, 1943b, p. 216, pl. 10, fig. 16. Kakio, Pliocene. Loc. I-2. Hypotype, GW.
—— *separans* (Brady). [*Nodosaria*]. Asano, 1938a, p. 210, pl. 27, fig. 58. Tomioka, Pliocene. Loc. K-7. Hypotype, GS.
—— *scalaris* (Batsch). [*Nautilus*]. Asano, 1938a, p. 210, pl. 25, fig. 28. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 27, figs. 11, 12. Kiwada, [Miocene]. Loc. J-4. Hypotype, GS.
—— —— *sagamiensis* Asano, 1936b, p. 613, pl. 30, figs. 6, 7. Tomioka, Pliocene. Loc. K-7. Holotype, GS, No. 21367.
—— —— —— Asano. Asano, 1938a, p. 211, pl. 25, fig. 24. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 28, figs. 17, 18. Kanazawa, Pliocene. Loc. K-5. Hypotype, GS. Also pl. 29, fig. 15. Konomine, Pliocene. Loc. M-2. Hypotype, GS.
Lenticulina fukushimaensis Asano, 1949b, p. 476, fig. *2*—3a, b. Asagai, Oligocene. Loc. C-1. Holotype, GS, No. 67032.
—— *japonica* Asano, 1936e, p. 328, pl. 37, figs. 7a, b. Dainichi, Pliocene. Loc. L-4. Holotype, GS, No. 21378. [*Planularia*].
—— *kakegawaensis* Asano, 1936e, p. 329, pl. 37, figs. 6a, b. Hosoya, Pliocene. Loc. L-3. Holotype, GS, No. 21379. [*Planularia*].
—— *kamakuraensis* Asano, 1936b, p. 612, pl. 31, figs. 1a, b. Tomioka, Pliocene. Loc. K-7. Holotype, GS, No. 21366.
—— —— Asano. Asano, 1938a, p. 205, pl. 25, fig. 16. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 28, fig. 9. Kanazawa, Pliocene. Loc. K-6. Hypotype, GS. Also pl. 30, fig. 4. Setana, Pliocene. Loc. C-8. Hypotype, GS. Also pl. 30, fig. 37. Sawane, Pliocene. Loc. F. Hypotype, GS. Also pl. 31, fig. 1. Tomioka, Pliocene. Loc. K-7. Topotype, GS.
—— *moniwaensis* Asano, 1937a, p. 32, figs. 1a, b. Moniwa, Miocene. Loc. E. Holotype, GS, No. 21401.
—— *rotulata* Lamarck. Hanzawa, 1931b, p. 167, pl. 28, figs. 15, 16. Lower Miocene. Loc. L-9. Hypotype, GS. [*Robulus*].
—— *totomiensis* Makiyama, 1931, p. 51, pl. 2, figs. 12, 14, 15. Kechienji, Pliocene. Loc. L-6. Holotype, GK.
Listerella bradyana tarukiensis Asano, 1936e, p. 326, pl. 36, figs. 5, 6. Dainichi, Pliocene. Loc. L-1. Holotype, GS, No. 21333. [*Martinottiella*].
Loxostoma etigoense Oinomikado, 1941a, p. 86, text-figs. 1a, b. Minakawa, Pliocene. Loc. G-1. Holotype, GT.
—— *karrerianum* (Brady). [*Bolivina*]. Asano, 1938e, p. 605, pl. 16, figs. 6a, b. Naganuma, Pliocene. Loc. K-7. Hypotype, GS.
Marginulina glabra d'Orbigny. Asano, 1938e, p. 210, pl. 27, fig. 9. Kiwada, [Miocene]. Loc. J-3. Hypotype, GS.
—— *nozimaensis* Asano, 1938a, p. 210, pl. 28, figs. 29–31. Kanazawa, Pliocene. Loc. K-8. Holotype, GS No. 21478.
—— *sendaiensis* Asano, 1937a, p. 33, text-fig. 6. Moniwa, Miocene. Loc. E. Holotype, GS, No. 21402.
—— *sendaiensis* Asano. Asano, 1938a, p. 209, pl. 28, figs. 22, 23. Hatsuse, Pliocene. Loc. K-9. Hypotype, GS.
—— *uedai* Asano, 1938a, p. 210, pl. 27, fig. 8. Kiwada, [Miocene]. Loc. J-3. Holotype, GS, No. 21479.
Nodosaria catenulata Brady. Asano, 1938a, p. 211, pl. 27, fig. 49. Tomioka, Pliocene. Loc. K-7. Hypotype, GS.
—— *inflexa* Schwager. Asano, 1938a, p. 212, pl. 29, fig. 20. Konomine, Pliocene. Loc. M-3. Hypotype, GS.
—— *insecta* Schwager. Asano, 1938a, p. 211, pl. 27, fig. 46. Kanazawa, Pliocene. Loc. K-5. Hypotype, GS.
—— *hirsuta* d'Orbigny. Asano, 1938a, p. 212, pl. 28, fig. 19. Kanazawa, Pliocene. Loc. K-4. Hypotype, GS. [*Lagenonodosaria*].

—— —— *aculeata* Cushman. Asano, 1938a, p. 212, pl. 25, fig. 19. Dainichi, Pliocene. Loc. L-4. Hypotype, GS. [*Lagenonodosaria*].
—— *kokozuraensis* Asano, 1949a, p. 426, fig. *1*—2, Kokozura, Miocene. Loc. O-2. Holotype, GS, No. 67043.
—— *raphana* (Linné). [*Nautilus*]. Asano, 1938a, p. 211, pl. 25, fig. 27. Hosoya, Pliocene. Loc. L-3. Hypotype, GS.
—— *subraphana* Asano, 1938a, p. 212, pl. 29, fig. 19. Konomine, Pliocene. Loc. M-2. Holotype, GS, No. 21480. Also pl. 30, figs. 33, 35. Natsukawa, Pliocene. Loc. G-4. Hypotype, GS.
—— *subscalaris pauci-costa* Cushman. Asano, 1938a, p. 212, pl. 29, fig. 21. Konomine, Pliocene. Loc. M-1. Hypotype, GS. [*Lagenonodosaria*].
—— *vertebralis* (Batsch). [*Nautilus*]. Asano, 1938a, p. 211, pl. 25, figs. 14, 29. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 27, fig. 60. Tomioka, Pliocene. Loc. K-7. Hypotype, GS. Also pl. 29, figs. 12, 13. Konomine, Pliocene. Loc. M-1. Hypotype, GS.
Nonion boueanum (d'Orbigny). [*Nonionina*]. Asano, 1938d, p. 595, pl. 15, figs. 5a, b. Setana, Pliocene. Loc. C-2. Hypotype, GS.
—— cf. *boueanum* (d'Orbigny). [*Nonionina*]. Asano, 1949b, p. 476, fig. *2*—4a, b. Asagai, Oligocene. Loc. O-1. Hypotype, GS, No. 67033.
—— *grateloupi* (d'Orbigny). [*Nonionina*]. Asano, 1938d, p. 594, pl. 15, fig. 14. Naganuma, Pliocene. Loc. K-7. Hypotype, GS.
—— *japonicum* Asano, 1938d, p. 593, pl. 15, figs. 1a, b; 2a, b. Naganuma, Pliocene. Loc. K-7. Holotype, GS, No. 21422.
—— *katayamai* Husezima and Maruhasi, 1944, p. 394, pl. 34, figs. 5a, b. Haizume, Pliocene. Loc. G-7. Holotype, NR.
—— *manpukujiense*, Otsuka, 1932, p. 634, text-fig. 5. Kakio, Pliocene. Loc. I-1. Holotype, GT.
—— *nakosoense* Asano, 1949a, p. 428, fig. *2*—14–17. Kokozura, Miocene. Loc. O-2. Holotype, GS, No. 67044.
—— *oyamai* Husezima and Maruhasi, 1944, p. 395, pl. 34, figs. 6a, b. Haizume, Pliocene. Loc. G-8. Holotype, NR.
—— *pompilioides* (Fichtel and Moll). [*Nautilus*]. Asano, 1938d, p. 596, pl. 15, figs. 13a, b. Konomine, Pliocene. Loc. M-2. Hypotype, GS.
—— —— *etigoense* Asano, 1938d, p. 596, pl. 15, figs. 10a, b. Natsukawa, Pliocene. Loc. G-5. Holotype, GS, No. 21425. [*Pullenia*].
—— *scaphum* (Fichtel and Moll). [*Nautilus*]. Asano, 1938d, p. 593, pl. 15, figs. 4a, b. Setana, Pliocene. Loc. C-3. Hypotype, GS.
—— *subturgidum* (Cushman). [*Nonionina*]. Asano, 1938d, p. 594, pl. 15, figs. 6a, b. Wakimoto, Pliocene. Loc. D-2. Hypotype, GS.
—— cf. *umbilicatulum* (Montagu). [*Nautilus*]. Asano, 1938d, p. 595, pl. 15, figs. 7a, b. Naganuma, Pliocene. Loc. K-7. Hypotype, GS.
Nonionella pulchella Hada. Asano, 1938d, p. 598, pl. 15, fig. 12. Setana, Pliocene. Loc. C-2. Hypotype, GS.
—— *umekae* Husezima and Maruhasi, 1944, p. 395, pl. 34, figs. 7a–c. Haizume, Pliocene. Loc. G-8. Holotype, NR. [*Nonionella japonica* (Asano)].
Oolina marginata (Walker and Boys). [*Serpula*]. Asano, 1938a, p. 218, pl. 27, figs. 30, 34. Tomioka, Pliocene. Loc. K-7. Hypotype, GS. [*Entosolenia*]. Also pl. 27, fig. 32. Kiwada, [Miocene]. Loc. J-2. Hypotype, GS. [*Entosolenia*]. Also pl. 29, fig. 30. Konomine, Pliocene. Loc. M-2. Hypotype, GS. [*Entosolenia*].
Patellinella hanzawai Asano, 1936b, p. 613, pl. 31, figs. 2a–c. Tomioka, Pliocene. Loc. K-7. Holotype, GS, No. 21368.
Parafrondicularia japonica Asano, 1938a, p. 189, pl. 25, fig. 26. Hosoya, Pliocene. Loc. L-3. Holotype, GS, No. 21457.
Planularia boso Asano, 1938a, p. 206, pl. 26, figs, 4, 6. Kiwada, [Miocene]. Loc. J-3. Hypotype. GS. [Holotype based on Pleistocene specimens],
—— *japonica* (Asano). [*Lenticulina*]. Asano. 1938a, p. 205, pl. 24, fig. 13. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 24, fig. 14. Dainichi, Pliocene. Loc. L-4. Holotype, GS, No. 21378. Also pl. 26, fig. 7. Kiwada, [Miocene]. Loc. J-3. Hypotype, GS.
—— *kakegawaensis* (Asano). [*Lenticulina*]. Asano, 1938a, p. 206, pl. 24, figs. 11, 12. Hosoya, Pliocene. Loc. L-3. Holotype, GS, No. 21379.
—— *nagaoi* Asano, 1938a, p. 206, pl. 30, fig. 1. Setana, Pliocene. Loc. C-8. Holotype, GS, No. 21471.
—— *tricarinella* (Reuss). [*Cristellaria*]. Asano, 1938a, p. 207, pl. 30, fig. 2. Setana, Pliocene. Loc. C-3. Hypotype, GS. Also pl. 30, fig. 30. Setana, Pliocene. Loc. C-7. Hypotype, GS.
—— *yabei* Asano, 1938a, p. 205, pl. 24, fig. 6. Hosoya, Pliocene. Loc. L-3. Holotype, GS, No. 21469.
Plectofrondicularia totomiensis Makiyama, 1931, p. 51, pl. 12, fig. 16. Kechienji, Pliocene, Loc. L-6. Holotype, GK.
Pleurostomella peregrina Yokoyama, 1890, p. 189, pl. 24, fig. 4. Poronai, [Oligocene]. Loc. B. Repository unknown.
Polymorphina charlottensis Cushman. Cushman and Ozawa, 1928b, p. 72, pl. 15, fig. 11. Sawane, Pliocene. Loc. F. Hypotype, GT.
—— —— Cushman, Cushman and Ozawa, 1930. p. 119, pl. 31, figs. 2–6. Natsukawa, Pliocene, Loc. G-3. Hypotype, NM.
—— —— Cushman, Asano, 1938b, p. 96, pl. 11, fig. 2. Setana, Pliocene. Loc. C-5. Hypotype GS.
—— *seminulina* Yokoyama, 1890, p. 189, pl. 24, fig. 17. Poronai, [Oligocene]. Loc. B. Repository unknown. [*Pseudopolymorphina*].
—— *yabei* Asano, 1937a, p. 33, text-figs. 5a–c. Moniwa, Miocene. Loc. E. Holotype, GS, No. 21403.
Polystomellina discorbinoides Yabe and Hanzawa, 1923, p. 99, text-figs. a–d. Natsukawa, Pliocene. Loc. G-3. Holotype, GS.
Pseudogaudryina ishikiensis Asano, 1949a, p. 426, fig. *1*—61–64. Kokozura, Miocene. Loc. O-2. Holotype and paratypes, GS, No. 67039.
Pseudononion japonicum Asano, 1936a, p. 347, text-figs. a–c. Naganuma, Pliocene. Loc. K-7. Holotype, GS, No. 21362. [*Nonionella*].

—— —— Asano. Asano, 1938d, p. 597, pl. 15, figs. 11a–c. Naganuma, Pliocene. Loc. K-7. Topotype, GS. [*Nonionella*].

—— *tredecum* Asano, 1936c, p. 622, pl. 33, fig. 7. Setana, Pliocene. Loc. C-2. Holotype, GS, No. 21375. [*Nonionella*].

Pseudoparrella japonica Asano, 1949a, p. 430, fig. 2—2–4. Kokozura, Miocene. Loc. O-2. Holotype and paratypes, GS, No. 67045.

Pseudopolymorphina compressa var. *okuwaensis* Cushman and Ozawa, 1928b, p. 71, pl. 13, fig. 7; pl. 15, figs. 8, 9. Sawane, Pliocene. Loc. F. Holotype, GT.

—— *hanzawai* Cushman and Ozawa, 1928a, p. 16, pl. 1, fig. 15. Sawane, Pliocene. Loc. F. Holotype, GT.

—— —— Cushman and Ozawa. Cushman and Ozawa, 1928b, p. 69, pl. 13, fig. 4; pl. 14, fig. 11; pl. 15, figs. 8, 9. Sawane, Pliocene. Loc. F. Topotype, GT.

—— —— Cushman and Ozawa. Cushman and Ozawa, 1930, p. 94, pl. 24, figs. 1a, b. Sawane, Pliocene. Loc. F. Topotype, NM.

—— *indica* var. *japonica* Cushman and Ozawa, 1928b, p. 71, pl. 13, fig. 6; pl. 15, fig. 6. Sawane, Pliocene. Loc. F. Holotype, GT.

—— *ishikawaensis* Cushman and Ozawa, 1928b, p. 70, pl. 13, fig. 5; pl. 15, fig. 5. Onma, Pliocene. Loc. H. Holotype, GT.

—— —— Cushman and Ozawa. Cushman and Ozawa, 1930, p. 98, pl. 25, figs. 4, 6. Onma, Pliocene. Loc. H. Holotype, GT.

—— —— Cushman and Ozawa. Asano, 1938b, p. 96, pl. 11, fig. 5. Setana, Pliocene. Loc. C-2. Hypotype, GS.

—— *okuwaensis* Cushman and Ozawa. Cushman and Ozawa, 1930, p. 98, pl. 25, figs. 2, 3. Onma, Pliocene. Loc. H. Topotype, NM.

—— *subglobosa* Cushman and Ozawa, 1930, p. 91, pl. 23, figs. 3a, b. Onma, Pliocene. Loc. H. Holotype, CL, No. 11663.

Pulvinulina japonica Yokoyama, 1890, p. 192, pl. 14, fig. 15. Poronai, [Oligocene]. Loc. B. Repository unknown.

—— *singularis* Yokoyama, 1890, p. 192, pl. 14, fig. 16. Poronai, [Oligocene]. Loc. B. Repository unknown. [*Anomalina*].

Pyrgo ezo Asano, 1938b, p. 93, pl. 9, figs. 1a, b. Setana, Pliocene. Loc. C-7. Holotype, GS, No. 21450.

—— *natsukawa* Matsui and Nakagawa, 1942, p. 361, text-figs. 2, 3. Natsukawa, Pliocene. Loc. G-2. Holotype, GK.

—— *yabei* Asano, 1936c, p. 621, pl. 33, figs. 1a, b; 5a, b. Setana, Pliocene. Loc. C-2. Holotype, GS, No. 21374.

—— —— Asano. Asano, 1938b, p. 93, pl. 9, figs. 5a, b; 7. Setana, Pliocene. Loc. C-2. Topotype, GS.

Quinqueloculina agglutinata Cushman. Asano, 1938b, p. 90, pl. 9, figs. 11a, b. Setana, Pliocene. Loc. C-3. Hypotype, GS.

—— *contorta striata* Asano, 1936d, p. 943, pl. 51, figs. 2a–c. Konomine, Pliocene. Loc. M-2. Holotype, GS, No. 21389.

—— *costata* d'Orbigny. Asano, 1938b, p. 92, pl. 10, figs. 6a–c. Setana, Pliocene. Loc. C-2. Hypotype, GS.

—— *dainitiensis* Asano, 1936e, p. 327, pl. 36, figs. 7a–c. Dainichi, Pliocene. Loc. L-1. Holotype, GS, No. 21334.

—— *hasimotoi* Asano, 1938b, p. 92, pl. 10, figs. 5a–c. Setana, Pliocene. Loc. C-2. Holotype, GS, No. 21449.

—— *kuromatunaiensis* Asano, 1936c, p. 621, pl. 32, figs. 4a–d. Setana, Pliocene. Loc. C-2. Holotype, GS, No. 21372.

—— *makiyamai* Ishizaki, 1943a, p. 19, pl. 1, figs. 9a–c. Kechienji, Pliocene. Loc. L-6. Holotype, GW.

—— *sagamiensis* Asano, 1936b, p. 612, pl. 30, figs. 5a–c. Tomioka, Pliocene. Loc. K-7. Holotype, GS, No. 21365.

—— *subagglutinata* Asano, 1936c, p. 620, pl. 32, figs. 1a–c. Setana, Pliocene. Loc. C-2. Holotype, GS, No. 21370.

—— —— Asano. Asano, 1938b, p. 91, pl. 9, figs. 8, 9. Setana, Pliocene. Loc. C-2. Topotype, GS.

—— *totomiensis* Asano, 1936e, p. 327, pl. 36, figs. 9a–c. Hosoya, Pliocene. Loc. L-3. Holotype, GS, No. 21335.

—— *vulgaris* d'Orbigny. Asano, 1938b, p. 91, pl. 10, figs. 4a–c. Setana, Pliocene. Loc. C-2. Hypotype, GS.

—— *yezoensis* Asano, 1936c, p. 620, pl. 32, figs. 3a–c. Setana, Pliocene. Loc. C-2. Holotype, GS, No. 21371.

—— —— Asano. Asano, 1938b, p. 91, pl. 10, figs. 7a, b. Setana, Pliocene. Loc. C-2. Topotype, GS.

Rectobolivina bifrons (Brady). [*Sagrina*]. Asano, 1938e, p. 606, pl. 16, figs. 11a, b. Hosoya, Pliocene. Loc. L-3. Hypotype, GS.

Robulus abensis Asano, 1936e, p. 327, pl. 37, figs. 5, 10. Negoya, Pliocene. Loc. L-8. Holotype, GS, No. 21336.

—— —— Asano. Asano, 1938a, p. 200, pl. 24, fig. 23; pl. 31, fig. 2. Negoya, Pliocene. Loc. L-8. Topotype, GS. Also pl. 28, fig. 14. Kanazawa, Pliocene. Loc. K-4. Hypotype, GS. Also pl. 29, fig. 1. Konomine, Pliocene. Loc. M-3. Hypotype, GS. Also pl. 29, fig. 2. Konomine, Pliocene. Loc. M-1. Hypotype, GS.

—— *bicostatus* Asano, 1936e, p. 328, pl. 37, figs. 1a, b. Dainichi, Pliocene. Loc. L-4. Holotype, GS, No. 21377.

—— —— Asano. Asano, 1938a, p. 199, pl. 24, fig. 15. Dainichi, Pliocene. Loc. L-4. Topotype, GS.

—— *calcar* (Linné). [*Nautilus*]. Asano, 1938a, p. 202, pl. 24, fig. 21. Nango, Pliocene. Loc. L-5. Hypotype, GS. Also pl. 28, fig. 8. Kanazawa, Pliocene. Loc. K-6. Hypotype, GS. Also pl. 29, fig. 5. Konomine, Pliocene. Loc. M-2. Hypotype, GS.

—— *calcarioides* Asano, 1938a, p. 200, pl. 24, fig. 20. Dainichi, Pliocene. Loc. L-4. Holotype, GS, No. 21459.

—— *costatus* (Fichtel and Moll) [*Nautilus*]. Asano, 1938a, p. 198, pl. 24, fig. 4. Hosoya, Pliocene. Loc. L-3. Hypotype, GS.

—— —— *multicostus* (Cushman). [*Cristellaria*]. Asano, 1938a, p. 199, pl. 24, fig. 7. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 26, fig. 5. Kiwada, [Miocene]. Loc. J-3. Hypotype,

GS. Also pl. 29, fig. 33. Konomine, Pliocene. Loc. M-2. Hypotype, GS.
—— —— *subdecoratus* (Cushman). [*Cristellaria*]. Asano, 1938a, p. 198, pl. 24, figs. 1–3. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 24, fig. 24. Nango, Pliocene. Loc. L-5. Hypotype, GS. Also pl. 29, fig. 34; pl. 31, fig. 4. Konomine, Pliocene. Loc. M-2. Hypotype, GS.
—— *depressus* Asano, 1938a, p. 202, pl. 25, fig. 15. Dainichi, Pliocene. Loc. L-4. Holotype, GS, No. 21462. Also pl. 26, fig. 27. Kiwada, [Miocene]. Loc. J-1. Hypotype, GS. Also pl. 28, fig. 11. Kanazawa, Pliocene. Loc. K-8. Hypotype, GS.
—— *etigoensis* Asano, 1938a, p. 203, pl. 30, fig. 38. Natsukawa, Pliocene. Loc. G-5. Holotype, GS, No. 21466.
—— *interruptus* Asano, 1938a, p. 204, pl. 30, figs. 5–7. Setana, Pliocene. Loc. C-7. Holotype, GS, No. 21467.
—— *iotus* (Cushman). [*Cristellaria*]. Asano, 1938a, p. 202, pl. 25, figs. 7, 11. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 28, fig. 1. Kanazawa, Pliocene. Loc. K-8. Hypotype, GS. Also pl. 28, fig. 2. Kanazawa, Pliocene. Loc. K-5. Hypotype, GS.
—— *kimituensis* Asano, 1938a, p. 203, pl. 26, figs. 15, 23. Kiwada, [Miocene]. Loc. J-1. Holotype, GS, No. 21463.
—— *kotiensis* Asano, 1938a, p. 203, pl. 29, fig. 35. Konomine, Pliocene. Loc. M-2. Holotype, GS, No. 21465.
—— *limbosus* (Reuss). [*Robulina*]. Asano, 1938a, p. 202, pl. 25, fig. 10. Kechienji, Pliocene. Loc. L-7. Hypotype, GS. Also pl. 30, fig. 29, Natsukawa, Pliocene. Loc. G-5. Hypotype, GS.
—— *miyagiensis* Asano, 1937a, p. 32, text-figs. 3a, b. Moniwa, Miocene. Loc. E. Holotype, GS, No. 21400.
—— *nikobarensis* (Schwager). [*Cristellaria*]. Asano, 1938a, p. 204, pl. 28, fig. 5. Kanazawa, Pliocene. Loc. K-5. Hypotype, GS. Also pl. 28, fig. 6. Kanazawa, Pliocene. Loc. K-8. Hypotype, GS. Also pl. 29, fig. 8. Konomine, Pliocene. Loc. M-2. Hypotype, GS.
—— *papillosus* (Fichtel and Moll). [*Nautilus*]. Asano, 1938a, p. 200, pl. 24, fig. 5. Nango, Pliocene. Loc. L-5. Hypotype, GS.
—— *pseudorotulatus* Asano, 1938a, p. 201, pl. 25, figs. 1, 4. Hosoya, Pliocene. Loc. L-3. Holotype, GS, No. 21460. Also pl. 25, fig. 3. Nango, Pliocene. Loc. L-5. Hypotype, GS. Also pl. 26, fig. 28. Kiwada, [Miocene]. Loc. J-1. Hypotype, GS. Also pl. 31, fig. 3. Moniwa, Miocene. Loc. E. Hypotype, GS.
—— *reniformis* (d'Orbigny). [*Cristellaria*]. Asano, 1938a, p. 204, pl. 29, fig. 9. Konomine, Pliocene. Loc. M-2. Hypotype, GS.
—— *sagamiensis* Asano, 1938a, p. 201, pl. 25, fig. 6. Dainichi, Pliocene. Loc. L-4. Hypotype, GS. Also pl. 28, fig. 12. Kanazawa, Pliocene. Loc. K-6. Holotype, GS, No. 21461. Also pl. 29, fig. 16. Konomine, Pliocene. Loc. M-2. Hypotype, GS.
—— *sasai* Asano, 1938a, p. 204, pl. 30, fig. 8. Setana, Pliocene. Loc. C-7. Holotype, GS, No. 21468.
—— *submamilligerus* (Cushman). [*Cristellaria*]. Asano, 1938a, p. 199, pl. 24, figs. 8, 10, 22. Hosoya, Pliocene. Loc. L-3. Hypotype, GS.
—— *surugaensis* Asano, 1936e, p. 328, pl. 37, figs. 4a, b. Negoya, Pliocene. Loc. L-8. Holotype, GS, No. 21376.
—— —— Asano. Asano, 1938a, p. 201, pl. 25, fig. 5. Negoya, Pliocene. Loc. L-8. Topotype, GS. Also pl. 25, fig. 12. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 28, fig. 7. Kanazawa, Pliocene. Loc. K-5. Hypotype, GS.
—— *tibaensis* Asano, 1938a, p. 203, pl. 26, fig. 16. Kiwada, [Miocene]. Loc. J-1. Holotype, GS, No. 21464. Also pl. 30, fig. 27. Natsukawa, Pliocene. Loc. G-5. Hypotype, GS.
—— *tumidus* Asano, 1938a, p. 200, pl. 24, fig. 9. Hosoya, Pliocene. Loc. L-3. Holotype, GS, No. 21458.
—— *lymani* Yokoyama, 1890, p. 193, pl. 24, fig. 18. Poronai, [Oligocene]. Loc. B. Repository unknown. [*Gyroidina*].
Rotalia nipponica Asano, 1936b, p. 614, pl. 31, figs. 2a–c. Tomioka, Pliocene. Loc. K-7. Holotype, GS, No. 21369.
—— *nitida* Reuss. Yokoyama, 1890, p. 193, pl. 14, fig. 2. Poronai, [Oligocene]. Loc. B. Repository unknown. [*Eponides*].
—— *schroeteriana* (Parker and Jones). Hanzawa, 1931a, p. 157, pl. 26, figs. 6–8. Misaka, Miocene. Loc. I-3. Hypotype, GS. [*Rotalia saipanensis* Hanzawa, MS.]
Saracenaria italica Defrance. Asano, 1938a, p. 207, pl. 29, fig. 10. Konomine, Pliocene. Loc. M-2. Hypotype, GS.
—— *latifrons* Brady. Asano, 1938a, p. 207, pl. 28, fig. 15. Kanazawa, Pliocene. Loc. K-4. Hypotype, GS.
—— (?) sp. Asano, 1949b, p. 476, fig. *1*–10. Asagai, Oligocene. Loc. O-1. Hypotype, GS, No. 67038.
Sigmoidella kagaensis Cushman and Ozawa, 1928a, p. 19, pl. 2, fig. 14. Onma, Pliocene. Loc. H. Holotype, GT.
—— —— Cushman and Ozawa. Cushman and Ozawa, 1928b, p. 76, pl. 13, fig. 15; pl. 16, fig. 9. Onma, Pliocene. Loc. H. Topotype, GT.
Sigmomorpha sadoensis Cushman and Ozawa, 1928a, p. 17, pl. 2, fig. 11. Sawane, Pliocene. Loc. F. Holotype, GT. [*Guttulina*].
—— —— Cushman and Ozawa. Cushman and Ozawa, 1928b, p. 73, pl. 13, figs. 9–11; pl. 16, figs. 2–3. Sawane, Pliocene. Loc. F. Topotype, GT. [*Guttulina*].
—— *sawanensis* Cushman and Ozawa, 1928b, p. 74, pl. 16, fig. 6. Sawane, Pliocene. Loc. F. Holotype, GT. [*Sigmomorphina*].
—— *trilocularis* (Bagg). [*Polymorphina*]. Cushman and Ozawa, 1928b, p. 74, pl. 16, fig. 5. Onma, Pliocene. Loc. H. Hypotype, GT. [*Sigmomorphina*].
Sigmomorphina hokkaidoensis Asano, 1938b, p. 97, pl. 11, fig. 10. Setana, Pliocene. Loc. C-7. Holotype, GS, No. 21453.
—— *kotoi* Cushman and Ozawa, 1930, p. 134, pl. 35, figs. 7a, b. Natsukawa, Pliocene. Loc. G-3. Holotype, CL, No. 11848.
—— *kuromatunaiensis* Asano, 1938b, p. 98, text-figs. 2a, b; 3a, b. Setana, Pliocene. Loc. C-1. Holotype, GS, No. 21455.

—— *nagaoi* Asano, 1938b, p. 97, pl. 11, fig. 1. Setana, Pliocene. Loc. C-7. Holotype, GS, No. 21452.
—— *sawanensis* (Cushman and Ozawa). [*Sigmomorpha*]. Cushman and Ozawa, 1930, p. 137, pl. 38, figs. 1a, b. Natsukawa, Pliocene. Loc. G-3. Hypotype, NM.
—— *sawanensis* (Cushman and Ozawa). [*Sigmomorpha*]. Asano, 1938b, p. 99, pl. 11, fig. 6. Setana, Pliocene. Loc. C-5. Hypotype, GS.
—— *setanaensis* Asano, 1938b, p. 98, text-figs. 1a, b. Setana, Pliocene. Loc. C-4. Holotype, GS, No. 21454.
—— *yokoyamai* Cushman and Ozawa, 1928a, p. 18, pl. 1, fig. 16. Sawane, Pliocene. Loc. F. Holotype, GT.
—— —— Cushman and Ozawa. Cushman and Ozawa, 1930, p. 136, pl. 36, figs. 6a, b. Sawane, Pliocene. Loc. F. Topotype, NM.
Spiroloculina costata Hada. Asano, 1938b, p. 92, pl. 10, fig. 8. Setana, Pliocene. Loc. C-2. Hypotype, GS. [*Spiroloculina hadai* Thalmann].
Streblus ketienziensis Ishizaki, 1948, p. 59, pl. 1, figs. 2a–c. Kechienji, Pliocene. Loc. L-7. Holotype, GW. [*Rotalia*].
—— *sikokuensis* Ishizaki, 1948, p. 61, pl. 1, figs. 1a–c. Konomine, Pliocene. Loc. M-2. Holotype, GW. [*Rotalia*].
—— *takanabensis* Ishizaki, 1948, p. 57, pl. 1, figs. 5a–c. Koonji, Pliocene. Loc. N. Holotype, GW. [*Rotalia*].
—— *tosaensis* Ishizaki, 1948, p. 56, pl. 1, figs. 6a–c. Konomine, Pliocene. Loc. M-2. Holotype, GW. [*Rotalia*].
—— *yabei* Ishizaki, 1948, p. 63, pl. 1, figs. 3a–c. Dainichi, Pliocene. Loc. L-2. Holotype, GW. [*Rotalia*].
Textularia aokii Asano, 1936e, p. 325, pl. 36, figs. 1a, b. Hosoya, Pliocene. Loc. L-3. Holotype, GS, No. 21330.
—— *uedai* Asano, 1936b, p. 611, pl. 30, figs. 1a–b. Tomioka, Pliocene. Loc. K-7. Holotype, GS, No. 21363.
Triloculina suttuensis Asano, 1936c, p. 621, pl. 33, figs. 2a–c. Setana, Pliocene. Loc. C-2. Holotype, GS, No. 21373.
—— —— Asano. Asano, 1938b, p. 93, pl. 9, figs. 10a, b. Setana, Pliocene. Loc. C-2. Topotype, GS.
Trochammina asagaiensis Asano, 1949b, p. 474, fig. *1*—2a–c. Asagai, Oligocene. Loc. O-1. Holotype, GS, No. 67030. Also fig. *1*—3, 4. Asagai, Oligocene. Loc. O-1. Paratype, GS.
Uvigerina aculeata d'Orbigny. Asano, 1938f, p. 613, pl. 17, fig. 23. Kiwada, [Miocene]. Loc. J-3. Hypotype, GS.
—— cf. *bifurcata* d'Orbigny. Asano, 1938f, p. 611, pl. 17, figs. 3, 4, 9. Wakimoto, Pliocene. Loc. D-2. Hypotype, GS.
—— *mediterranea* Hofker. Asano, 1938f, p. 612, pl. 17, fig. 8. Naganuma, Pliocene. Loc. K-7. Hypotype, GS. Also pl. 17, figs. 10, 11. Kanazawa, Pliocene. Loc. K-1. Hypotype, GS. Also pl. 17, figs. 14, 15. Kechienji, Pliocene. Loc. L-7. Hypotype, GS.
—— cf. *peregrina* Cushman. Asano, 1938f, p. 614, pl. 17, fig. 18. Wakimoto, Pliocene. Loc. D-2. Hypotype, GS.
—— *pygmaea* d'Orbigny. Asano. 1938f, p. 611, pl. 17, figs. 5–7. Wakimoto, Pliocene. Loc. D-2. Hypotype, GS.
—— *schwageri* Brady. Asano, 1938f, p. 612, pl. 17, figs. 19, 20. Hosoya, Pliocene. Loc. L-3. Hypotype, GS. Also pl. 17, figs. 24, 30. Kiwada, [Miocene]. Loc. J-3. Hypotype, GS.
—— *substriata* Asano, 1938f, p. 614, pl. 17, fig. 22. Kiwada, [Miocene]. Loc. J-4. Paratype, GS. [Holotype based on Pleistocene specimens].
—— *tenuistriata* Reuss. Asano, 1938f, p. 612, pl. 17, figs. 12, 13. Naganuma, Pliocene. Loc. K-7. Hypotype, GS.
—— *yabei* Asano, 1938f, p. 613, pl. 17, figs. 1, 2. Wakimoto, Pliocene. Loc. D-2. Holotype, GS, No. 21429.
Vaginulina awaensis Asano, 1938a, p. 208, pl. 26, figs. 8, 9. Kiwada, [Miocene]. Loc. J-3. Holotype, GS, No. 21477.
—— *boso* Asano, 1938a, p. 208, pl. 27, fig. 3. Kiwada, [Miocene]. Loc. J-1. Holotype, GS, No. 21474.
—— *lata* (Cornuel). [*Marginulina*]. Asano, 1938a, p. 209, pl. 28, fig. 20. Kanazawa, Pliocene. Loc. K-1. Hypotype, GS. Also pl. 25, fig. 4. Kechienji, Pliocene. Loc. L-7. Hypotype, GS.
—— cf. *linearis* (Montagu). [*Nautilus*]. Asano, 1938a, p. 209, pl. 29, figs. 17, 18. Konomine, Pliocene. Loc. M-2. Hypotype, GS. [*Vaginulina asanoi* (Ishizaki)].
—— *miuraensis* Asano, 1938a, p. 207, pl. 28, fig. 25. Hatsuse, Pliocene. Loc. K-9. Paratype, GS. Also pl. 28, fig. 26. Hatsuse, Pliocene. Loc. K-10. Holotype, GS, No. 21473.
—— *tibaensis striata* Asano, 1938a, p. 208, pl. 27, fig. 6. Kiwada, [Miocene]. Loc. J-1. Holotype, GS, No. 21476.
Vaginulinopsis asanoi Ishizaki, 1942, p. 106, text-figs. 1–3. Koonji, Pliocene. Loc. N. Holotype, GW. [*Vaginulina*].
Virgulina ishikiensis Asano, 1949a, p. 428, fig. *1*—45, 46, 48, 56. Kokozura, Miocene. Loc. O-2. Holotype and paratypes, GS, No. 67041.

NOTES ON THE SMALLER FORAMINIFERA FROM JAPAN

Analytical research on the smaller foraminifers in Japan is in its infancy and relatively little attention has so far been given to specimens from formations older than Pliocene. Research is also needed to improve the identifications of some of the species. Consequently, one cannot at this time do more than offer a few general statements designed primarily to draw attention to the need for more intensive studies.

Upper Cretaceous smaller foraminifers, including *Globotruncana*, *Nodosaria* and *Robulus* are present in Hokkaido. These specimens have not yet been described and the locality data have not been published.

No Paleocene and Eocene smaller Fora-

minifera are as yet known in Japan proper, but the Poronai shale of Hokkaido locally contains Oliogocene species. These Poronai specimens were described by M. Yokoyama (1890) as "Cretaceous." Recently the present author published a paper on Foraminifera from the Asagai formation, Jo-ban district of Honshu, which is probably Oligocene.

The Miocene smaller foraminifers have not received detailed attention. The genera most commonly recognized are *Cyclammina*, *Elphidium*, *Hanzawaia*, *Haplophragmoides*, *Lagenonodosaria*, *Nonion*, *Nonionella*, *Rotalia*, *Robulus*, *Uvigerina*, *Vaginulina* and *Valvulineria*. The Miocene species from the Moniwa formation, near Sendai, are limited to northeastern Japan. The Foraminifera from the Kokozura formation, Jo-ban district, comprise an assemblage different from those of the Japanese Pliocene formations but similar to the assemblages of the Californian Miocene. The geological age of the Kiwada formation in Boso Peninsula, Chiba Prefecture, cannot be determined with the scanty foraminiferal material at hand, but it may be Miocene to judge from the occurrence of such Miocene mollusca as *Periploma pulchellum* Hatai and Nishiyama and *Patinopecten kimurai* (Yokoyama).

The foraminiferal fauna from the Pliocene formations of Japan is characterized by two assemblages, one from the Japan Sea side (Hokkaido, Aomori, Akita, Niigata and Ishikawa) and the other from the Pacific side (Chiba, Kanagawa, Shizuoka, Kochi and Miyazaki). The assemblage from the Japan Sea area (Table 1) includes species belonging to the families Cassidulinidae, Polymorphinidae, Nonionidae and Uvigerinidae which seem to be related to species from the Pliocene of California, although the specific names are different. The assemblage from the Pacific area (Table 2) is characterized by species of *Robulus*, *Planularia*, *Vaginulina*, and *Hanzawaia*, some of which are living in the adjacent seas of the Philippine and Malay archipelagoes.

The Pleistocene Foraminifera of Japan, in contrast to those from Pliocene formations, generally consist of Recent forms which are common in the adjacent seas of Japan. No clear-cut boundary between the Pleistocene and Pliocene has yet been determined from studies of foraminiferal assemblages.

TABLE 1—CHARACTERISTIC PLIOCENE SPECIES OF JAPAN SEA AREA

	Loc. A	Loc. C	Loc. D	Loc. F	Loc. G	Loc. H
Cassidulina japonica Asano and Nakamura		×	×	×	×	×
C. setanaensis Asano and Nakamura		×				
C. yabei Asano and Nakamura		×	×	×	×	×
Cribroelphidium ezoense (Asano)	×					
C. yabei (Asano)		×	×	×		
Dentalina setanaensis Asano		×	×	×	×	×
Entosolenia circulo-costa (Asano)		×		×	×	
Elphidiella nagaoi Asano		×	×			
Elphidium hanzawai Asano			×		×	
Eponides sasai Asano		×				
Gaudryina yabei Asano			×			
Guttulina sadoensis (Cushman and Ozawa)		×	×	×	×	×
Karreriella baccata japonica Asano		×		×	×	
Planularia nagaoi Asano		×				
Polystomellina discorbinoides Yabe and Hanzawa			×	×	×	
Pseudopolymorphina ishikawaensis Cushman and Ozawa		×	×	×	×	×
P. okuwaensis Cushman and Ozawa		×	×	×	×	×
Pyrgo ezo Asano		×	×	×	×	
Quinqueloculina kuromatunaiensis Asano		×		×		
Q. subagglutinata Asano		×		×	×	
Q. yezoensis Asano		×		×		
Sigmomorphina kuromatunaiensis Asano		×				
S. setanaensis Asano		×		×		
S. hokkaidoensis Asano		×				
Uvigerina yabei Asano		×	×	×		

TABLE 2—CHARACTERISTIC PLIOCENE SPECIES OF PACIFIC AREA

	Loc. I	Loc. J	Loc. K	Loc. L	Loc. M	Loc. N
Baggina totomiensis Makiyama	×	×	×	×	×	
Bolivina hanzawai Asano				×	×	
Clavulina tosaensis Asano					×	
C. yabei Asano		×		×		
Dyofrondicularia nipponica Asano				×		
Gaudryina ogasaensis Asano			×	×	×	
Hazawaia nipponica Asano	×	×	×	×		
Lagenonodosaria scalaris sagamiensis Asano	×	×	×	×	×	×
L. hyugaensis (Oinomikado)				×	×	×
Lenticulina kamakuraensis Asano	×	×	×	×	×	×
L. totomiensis Makiyama				×		
Marginulina nozimaensis Asano			×			
Nonion manpukujiense Otsuka	×	×	×	×	×	
Parafrondicularia japonica Asano				×		
Planularia boso Asano		×		×		
P. japonica (Asano)		×		×	×	
P. kakegawaensis (Asano)				×		
P. yabei Asano				×		
Quinqueloculina dainitiensis Asano				×		
Q. sagamiensis Asano	×	×	×	×	×	
Q. totomiensis Asano			×	×		
Robulus abensis Asano	×	×	×	×	×	
R. costatus multicostus (Cushman)	×	×	×	×	×	
R. costatus subdecoratus (Cushman)	×		×	×	×	×
R. nikobarensis (Schwager)	×	×	×	×	×	×
R. pseudorotulatus Asano	×	×	×	×	×	×
R. submamilligerus (Cushman)	×		×	×	×	
R. kotiensis Asano					×	
Rotalia ketienziensis (Ishizaki)		×	×	×	×	×
R. sikokuensis (Ishizaki)					×	
R. takanabensis (Ishizaki)	×			×	×	×
R. tosaensis (Ishizaki)					×	×
R. yabei (Ishizaki)	×			×	×	×
Textularia uedai Asano		×	×		×	
Uvigerina schwageri Brady	×	×		×	×	
U. substriata Asano		×				
Vaginulina asanoi (Ishizaki)					×	×
V. awaensis Asano		×				
V. miuraensis Asano			×			
V. tibaensis Asano		×				

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UPPER CAMBRIAN FAUNAS OF THE LITTLE ROCKY MOUNTAINS, MONTANA

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ABSTRACT—The only complete sequence of Upper Cambrian rocks in this area occurs in a 600 ± foot section measured along Lodge Pole Creek. The section displays intercalated green shales, thin gray limestones and gray-green limestone pebble conglomerates with the upper 100 feet characterized by a reddish-buff coloration. The sequence is a typical development of the Pilgrim formation of central Montana, and contains Dresbachian, Franconian and probable Trempealeauian equivalents. Faunas assignable to the *Cedaria*, *Crepicephalus*, *Elvinia*, *Conaspis*, *Ptychaspis-Prosaukia* and lower *Dikelocephalus* zones are described. Most of the species have been previously described from Montana, Alberta, Wyoming and the Upper Mississippi Valley. Five new species and one new genus are described.

INTRODUCTION

DURING the field seasons of 1937 and 1938 the Little Rocky Mountains were visited for periods of four or five days in order to examine the Cambrian section and collect fossils. The Cambrian exposed in the Little Rockies represents the northeastern-most outcrop of Cambrian in the Cordilleran province and a determination of its relationship, lithologically and faunally, was considered essential to the complete understanding of both the central Montana and the southern Montana sections. The material was not included in the first paper dealing with the central Montana Upper Cambrian faunas (Lochman and Duncan, 1944) because the collections are small and it was hoped that future collecting could augment them. However, circumstances have prevented a return to the region, so the specimens are now placed on record, with the hope that in the future truly representative assemblages may be obtained. Only one species, *Arapahoia stantoni* Resser has been previously described from the region.

I wish to acknowledge the very kind assistance and co-operation of Dr. M. M. Knechtel during both trips. The expense of photography of the specimens was defrayed by a grant-in-aid from the Geological Society of America.

DISCUSSION OF SECTIONS

In the Little Rocky Mountains the Precambrian core appears to have been raised to its present position primarily by faulting. The faults crop out mainly within the Cambrian beds with the result that at present only the section exposed along Lodge Pole Creek is believed to represent an unbroken Upper Cambrian sequence. In the Middle Cambrian, in ascending order, the Flathead sandstone, the Wolsey sandy micaceous shale, the Meagher limestone (only 2 feet thick) and the Park dark green shales with limestone nodules near the top can be recognized. The Upper Cambrian Pilgrim formation is a thick monotonous succession of intercalated green shales, thin limestones, limestone nodules and pebble conglomerates. The top 100 feet has a noticeable red and buff coloration, much less shale and a higher lime content. The maroon dolomitic siltstones of the typical Dry Creek formation occur not at the top of the Pilgrim formation, but overlie the Bighorn dolomite, and have been shown by Sloss and Laird (1947) to belong to the Devonian cycle of sedimentation. The name Dry Creek shale should be used only as originally defined by A. C. Peale in 1893 (Lochman, in press), and the Pilgrim is the only Upper Cambrian formation to be recognized in central Montana.

On Lodge Pole Creek the Upper Cambrian portion of the section was measured and collections were made from the base of the Middle Cambrian to the top of the Upper Cambrian. The measured section is given and discussed below. On Sipary Ann Butte (Thorn Hill Butte) southwest of Landusky, 433 feet of Upper Cambrian is

exposed. The section starts near the base of the butte in a gully with apparently very early Upper Cambrian beds overlying a Tertiary sill. Near the top the section has been shortened by faulting. Several collections were obtained from this section, but all the specimens are poorly preserved because of partial metamorphism by the sill. An attempt was made to examine the section along Beaver Creek, but exposures are very poor and no significant outcrops were seen until the old Beaver Mines were reached. Here the Pilgrim is better exposed but the base of the section is a fault contact with porphyry and at the top the section ends with another fault contact between porphyry and Bighorn dolomite. Moreover, the beds have been somewhat altered throughout by the igneous intrusions. Fossils were collected from a few other Cambrian outcrops scattered through the region. but each of these localities is an isolated exposure of beds.

List of Localities and Collection Numbers:

On North fork of the South fork of White Cow Creek

C1—reddish buff, thin-bedded sandy dolomite and pebble conglomerate—3 feet below base of Bighorn dolomite.

Outcrops along Landusky—Hays Road

C1a—limestone pebble conglomerate and limestone nodules in shale—just south of Mission Peak.

C2—limestone pebble conglomerate in shale—along road between Landusky and Little Ben Mine.

Outcrops in small valley just east of Landusky

D1—limestone pebble conglomerate in green shales.

Outcrops on hillside just above ruins of old mine mill at Beaver Mines

E1—pebble conglomerate at mine opening.

E2—loose piece approximately 60 feet above mine opening.

E3—loose piece approximately 75 feet above mine opening.

Lodge Pole Creek section

B0, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10, B11, B12—note positions in section given below

Sipary Ann Butte (Thorn Hill Butte) section

A1—lowest 5 feet of pebble conglomerates and shales, just above sill in gully.

A2 and $A2_1$—15 to 20 feet above sill.

A3, A4, A5—in cliff outcrop of edgewise pebble conglomerate, approximately 140 feet above the sill.

A6—at about 65 feet below base of Bighorn dolomite.

A7—at about 50 feet below base of Bighorn dolomite.

SECTION ON LODGE POLE CREEK	Feet
Base of Bighorn formation	
Upper Cambrian—Pilgrim formation	
1. Covered slope, red and buff coloration; B13—loose limestone slab 20′ from top	33.2
2. Red and buff mottled limestone pebble conglomerates with intercalated thin green shales, platy gray limestones and buff limestone; B12, at base of 3rd big pebble conglomerate from top, approx. 40′ from top; B11 in basal beds of this unit	70.57
3. Covered slope, gray-green coloration.	24.4
4. Thin bedded limestones and dark green shales intercalated with thick and thin beds and lenses of edgewise pebble conglomerate; *Ptychaspis-Prosaukia* zone—B10, 28′ from top of unit; B9, 41′ from the top of unit; B8, 49.57′ from top of unit; B5, at base of unit	69.81
5. Largely covered, a few shales and thin limestones exposed down in stream bed; B7 and B6 near middle of unit	19.6
6. Largely covered, a few scattered small shale outcrops in upper 30′ on northwest side of stream, rest completely covered	92.08
7. Gray-green fissile shales, thin gray limestones, limestone pebble conglomerates in beds and lenses, and limestone nodules, well exposed at several bends of the stream: *Crepicephalus* zone, B4, upper 10′ of shale; B3, limestone pebble conglomerates, approximately 10′ thick, 38.02′ below top of unit; *Cedaria* zone—between 99′ and 119.1′ below top of unit is a prominent outcrop of thick-bedded pebble conglomerate on southeast side of stream, carrying fragments of *Arapahoia;* B2, intercalated shales and pebble conglomerates between 119.1′ and 153.5′ below top of unit	153.54
8. Covered slope	20.5

9. Partially covered area, few scattered outcrops of green shales and limestone pebble conglomerates seen low in stream bed; *Cedaria* zone—B1, shales at base of this unit..... 54.61

Proven thickness of Pilgrim formation..... 538.31

Beds of uncertain age—

10. Completely covered area along stream bed; B0, loose piece of pebble conglomerate with *Arapahoia* and *Dicellomus* in stream bed approximately 30′ from base of unit..... 103.31

Middle Cambrian—Park formation

11. Low cliff of gray limestone nodules and pebble conglomerates in shales, opposite abandoned cabin; Park fauna collected here.

The Pilgrim formation on Lodge Pole Creek has a thickness of 538.31 feet from the contact with the Bighorn dolomite to the lowest exposed outcrop from which fossils of the *Cedaria* zone were obtained. Between this shale bed and the next exposed beds upstream, from which Middle Cambrian Park fossils were obtained, is a covered area of approximately 103 feet. The Middle-Upper Cambrian gradational contact is somewhere within this thickness. The recovery of the loose piece of *Cedaria* zone pebble conglomerate—B0—only 30 feet downstream from the highest Middle Cambrian outcrop suggests that the contact is near the base of the 103 foot unit. Thus the Pilgrim formation in the Little Rocky Mountains may have a thickness of as much as 641 feet or possibly as little as 550 feet, and this thickness is known from the fossils to be the equivalent of at least all the Dresbachian and Franconian. The age of the 73 feet above collection B12 is not definitely known but it may be safely assumed that some of the beds are a Trempealeau equivalent. As the Lodge Pole Creek section represents the most northeastern exposed section of Upper Cambrian within the Cordilleran trough, it is noteworthy that lithologically and faunally it is obviously related to and one of the other central Montana Upper Cambrian sections (Lochman and Duncan, 1944). The closest section geographically is that at Half Moon Pass in the Big Snowy Mountains (Deiss, 1936). Here the Pilgrim formation, as now recognized, has a thickness of 685 feet and a known age range from lowermost *Cedaria* zone into the *Bellefontia* zone of the earliest Ordovician. The decrease in thickness of the Pilgrim formation in the Lodge Pole Creek section may be accounted for by the absence of the Lower Ordovician, as no evidence of the *Bellefontia* zone has been obtained here.

DISCUSSION OF FAUNAL ZONES

The species obtained in each collection are arranged in the faunal lists by the recognized faunal zones to which they belong, and the significant features of the various faunas are discussed below.

FAUNAL LISTS

cf. Lower *Dikelocephalus* Zone Fauna

B12—*"Agnostus"* sp.
Plethometopus albertensis Resser

B11—*Protospongia*? sp. undet.

Ptychaspis-Prosaukia Zone Fauna

EXPLANATION OF PLATE 46

FIGS. *1–7*—*Plethometopus albertensis* Resser. *1*, largest cranidium, slightly flattened, ×3; *2*, small cranidium, with occipital spine, ×3; *3*, small unpeeled cranidium with occipital spine, ×4; *4*, largest pygidium, ×6; *5*, a small peeled cranidium, ×3; *6*, a perfect small pygidium, ×6; *7*, two free cheeks, one nearly complete, ×4, all hypotypes from collection B12. (p. 328)

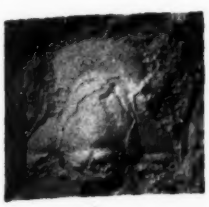
8–10—*Monocheilus* sp. undet. Three specimens of the distinctive free cheek of this genus, ×2; *8*, *10*, collection B10; *9*, collection B8. (p. 329)

11–13—*Idahoia wisconsensis* (Owen). *11*, a large fragmentary free cheek, ×1; *12*, small broken cranidium with complete occipital spine, ×2; *13*, external shale mold of small cranidium, ×2, all hypotypes from collection B8. (p. 329)

14—*Pseudagnostus josepha* (Hall). Two fragmentary cephala, ×2, hypotypes from collection B10. (p. 329)

15–17—*Wilbernia explanata* (Whitfield). *15*, large fragmentary cranidium, ×1; *16*, smaller, nearly perfect cranidium, ×2, hypotypes, collection B9; *17*, small, complete but crushed cranidium, ×2, hypotype, collection B10. (p. 330)

18—*Protospongia?* sp. undet. small portion of surface of slab scattered with sponge spicules, ×3, collection B11. (p. 328)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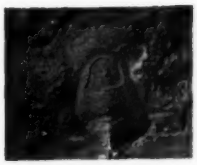
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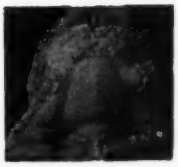
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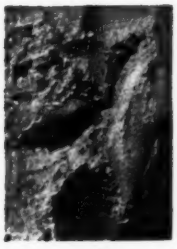
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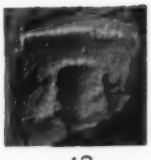
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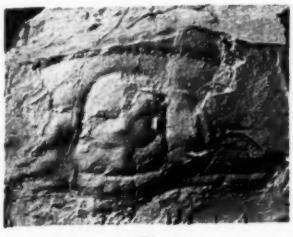
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Lochman, Montana Upper Cambrian fauna

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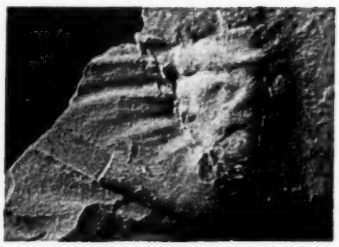
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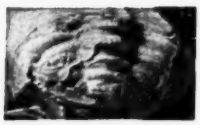
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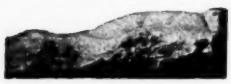
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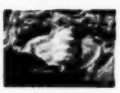
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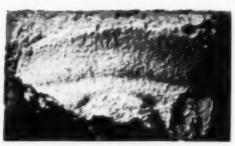
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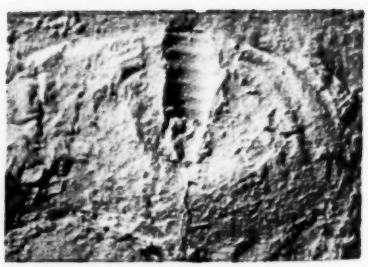
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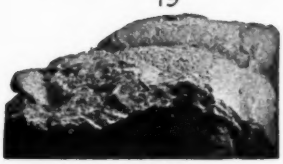
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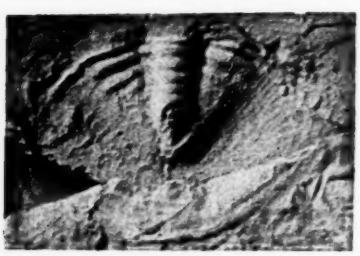
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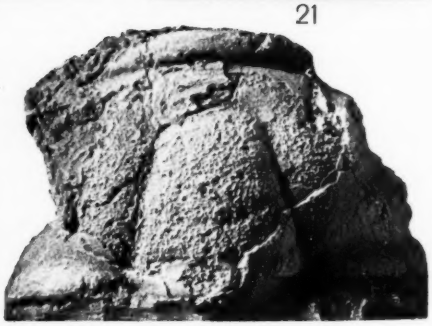
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Lochman, Montana Upper Cambrian fauna

B10—*Wilbernia explanata* (Whitfield)
Idahoia wisconsensis (Owen)
Pseudagnostus josepha (Hall)
Ptychaspis striata Whitfield
Monocheilus sp. undet.
B9 —*Wilbernia explanata* (Whitfield)
Pseudagnostus josepha (Hall)
B8 —*Idahoia wisconsensis* (Owen)
Ptychaspis striata Whitfield
Monocheilus sp. undet

Conaspis Zone Fauna

E3 —*Maustonia cordillerensis* Lochman, n. sp.

Elvinia Zone Fauna

E2 —*Elvinia roemeri* (Shumard)
cf. *Burnetia* sp.
B7 —*Pterocephalia bridgei* Resser
Berkeia occidentalis Lochman, n. sp.
Iddingsia sp. undet.

Crepicephalus Zone Fauna

B4 —*Coosia albertensis* Resser
Coosia modesta Lochman
Crepicephalus buttsi montanensis Lochman
Holcacephalus cf. *H. robustus* Lochman
Maryvillia violaensis Resser
B3 —*Coosia albertensis* Resser
Crepicephalus buttsi montanensis Lochman
Dresbachia amata Walcott
Maryvillia alberta Resser
Uncaspis aff. *U. unca* (Walcott)
"*Agnostus*" sp.

Cedaria Zone Fauna

D1 —*Arapahoia aspinosa* Lochman
Arapahoia snowiensis Howell and Duncan
Syspacheilus occidens Lochman, n. sp.
cf. *Syspacheilus occidens* Lochman, n. sp.
Tricrepicephalus sp. undet.
E1 —*Arapahoia* sp. undet.
C1a—*Arapahoia aspinosa* Lochman
Arapahoia snowiensis Howell and Duncan
C2 —*Kinsabia* cf. *K. varigata* Lochman
A3 —*Arapahoia snowiensis* Howell and Duncan
Kormagnostus esterius Lochman
Millardia sp.
Tricrepicephalus aff. *T. simulans* Resser
B2 —*Arapahoia aspinosa* Lochman
Arapahoia snowiensis Howell and Duncan
Arapahoia stantoni Resser
Homagnostus sp. undet.
Kinsabia cf. *K. varigata* Lochman
Menomonia sp. undet.
Tricrepicephalus sp. undet.
Uncaspis presbytera Lochman, n. sp.
B1 —*Arapahoia snowiensis* Howell and Duncan
Homagnostus cf. *H. lochmanae* Howell and Duncan
B0 —*Kinsabia* cf. *K. varigata* Lochman
Arapahoia stantoni Resser

Lowest *Cedaria* Subzone Fauna

EXPLANATION OF PLATE 47

FIGS. *1–5*—*Ptychaspis striata* Whitfield. *1*, largest cranidium, ×2; *2*, smaller, more complete cranidium, ×2½, hypotypes, collection B8. *3*, *4*, fragments of large pygidia, ×2½; *5*, a large, somewhat crushed free cheek, ×1, hypotypes, collection B10. (p. 330)

6–13—*Maustonia cordillerensis* Lochman, n. sp. *6*. *7*, side and dorsal views of holotype cranidium; *8*, dorsal view of smaller, more complete cranidium; *9*, *13*, dorsal and side views of largest pygidium; *11*, *12*, two smaller pygidia; *10*, a small free cheek, all ×2, collection E3. (p. 331)

14–18—*Pterocephalia bridgei* Resser. *14*, shale mold of medium-size pygidium, ×3; *15*, medium-size pygidium showing striae on doublure, ×3; *16*, a small cranidium, ×2; *17*, shale mold of a small pygidium, ×3; *18*, shale mold of small cranidium showing complete preglabellar area, ×2, hypotypes, collection B7. (p. 334)

19—cf. *Burnetia* sp. Fragment of anterior portion of cranidium, ×2, collection E2. (p. 334)

20—*Iddingsia?* sp. undet. Single crushed and fragmentary cranidium, ×2, collection B7. (p. 334)

21–23—*Elvinia roemeri* (Shumard). *21*, *23*, side and dorsal views of cranidium, ×2; *22*, a fragmentary free cheek, ×2, hypotypes, collection E2. (p. 333)

A1, A2, A2'—*Armonia lata* (Howell and Duncan)
Cedarina cordillerae (Howell and Duncan)
Knechtelia ann Lochman, n. gen., n. sp.
Kormagnostus esterius Lochman

Due to the small size of these collections only a few significant correlations and relationships are indicated by the faunal assemblages.

Cf. Lower Dikelocephalus *Zone Fauna.*—With one exception, the small collection B12 contains the latest Upper Cambrian trilobites yet obtained in the Little Rocky Mountains. *Plethometopus albertensis* Resser is the only significant species, and was originally described from Alberta where the type occurs on the same piece of rock with a species of *Ellipsocephaloides* and one of *Chariocephalus.* In the Wisconsin standard section these two genera make their appearance at the middle of the *Ptychaspis-Prosaukia* zone, *Ellipsocephaloides* first appearing at the top of the *Ptychaspis* subzone, and *Chariocephalus* in the overlying base of the *Prosaukia* subzone, to which it is restricted. *Plethometopus* appears in Wisconsin in the succeeding Lower *Dikelocephalus* zone. The abundant occurrence of *Plethometopus* in the eastern Canadian and Vermont sections suggests that it was a boreal genus which moved southward into the Cordilleran and Appalachian troughs. *Ellipsocephaloides* appears to have been indigenous to the Cordilleran trough or the Upper Mississippi Valley region. As collection B12 lies about 82 feet above collection B10, which can be accurately placed at the middle of the *Ptychaspis-Prosaukia* zone, it appears most reasonable to consider collection B12 somewhat younger in age, i.e., in the uppermost faunal zone of the Franconian. The highest collection B13 in the Lodge Pole Creek section comprises several loose slabs of buff limestone obtained 53 feet above collection B12. It contains only several brachiopods which will be described by Dr. Charles Bell at a later date.

The question remains as to whether the 73 foot interval above collection B12 contains only a Trempealeau equivalent or a Trempealeau and Lower Ordovician sequence as occurs in the Half Moon Pass section of the Big Snowy Mountains. A comparison of thicknesses suggests that only beds of Trempealeauian age are present, since in the Half Moon Pass section approximately 115 feet of beds above the *Ptychaspis-Prosaukia* zone can be assigned to late Upper Cambrian and the overlying 127 feet belong to the Lower Ordovician. The known Trempealeau equivalent of the southern Montana sections, the Grove Creek formation, averages 35 feet in thickness throughout that region.

The one exception mentioned above refers to the two trilobites obtained in the small, poorly preserved collections A6 and A7 from Sipary Ann Butte. This material was obtained between 50 and 65 feet from the base of the Bighorn dolomite in buff pebble conglomerates. In this section a fault occurs about 107 feet below the base of the Bighorn dolomite, and the lithology of the beds changes abruptly from gray-green shales and pebble conglomerates to buff and red platy limestone, and pebble conglomerates intercalated with light gray shales. A *Stenopilus* and a new genus which characterizes the unnamed fauna of central and southern Montana occur in the collection. This genus is the form which unfortunately was identified as *Aphelaspis* in the field and so reported in 1944 (Lochman and Duncan, p. 31). Collections of this unnamed fauna have now been obtained from sections in Montana, Wyoming and the Black Hills, and will be studied and described in the immediate future.

Ptychaspis-Prosaukia *Zone Fauna.*—Although collections B8, B9 and B10 are small, they contain adequately preserved specimens which can be accurately identified. All identifiable species of the fauna are species which have been previously described from the Upper Mississippi Valley. As this is the first description of a faunal assemblage of this age not only from Montana, but from any of the area between the Cordilleran trough and Wisconsin, no peculiar significance can be attached to the close affinities of the faunas. The species of the two regions would be expected to show a fairly close relationship between the faunal assemblages as

both areas lay south of an apparently continuous Canadian shoreline, and these shallow coastal seaways, characterized by similar environments, would have facilitated the movement of the species. However, more faunas from this zone in Montana, Wyoming and South Dakota must be described before the configuration of this northeastern shoreline and the details of faunal migration can be accurately charted.

In the Wisconsin standard section Raasch (personal communication June 10, 1948) now recognizes five divisions in the lower *Ptychaspis* subzone and five in the upper *Prosaukia* subzone. A special *Briscoia* zone or subzone is no longer recognized since species of *Briscoia* are now known to occur as low as division 1 of the *Prosaukia* subzone though they are most common in the top divisions 4 and 5. *Ptychaspis striata* (Whitfield) is the diagnostic species of division 5 of the *Ptychaspis* subzone; *Idahoia wisconsensis* (Owen) occurs in divisions 4 and 5; and *Wilbernia explanata* (Whitfield) occurs in divisions 2 and 3. *Pseudagnostus josepha* (Hall) first appears near the top of the *Conaspis* zone, and is recorded from divisions 1, 3–5 of the *Ptychaspis* subzone. Thus the Montana faunal assemblage of these four species is dated as approximately the top of the *Ptychaspis* subzone, i.e., the middle of the *Ptychaspis-Prosaukia* zone.

Conaspis *Zone Fauna.*—The small collection E3 consisting only of the new species *Maustonia cordillerensis* Lochman is important evidence of the presence of the zone in this region. But as *Conaspis* zone assemblages from the other central Montana sections have not yet been described, no pertinent comparisons can be made. It is known that this same species, *M. cordillerensis*, does occur in the middle part of the *Conaspis* zone of the Wisconsin sections.

Elvinia *Zone Fauna.*—Two small collections, E2, containing *Elvinia roemeri* (Shumard) and a *Burnetia*, and B7 with *Pterocephalia* and *Berkeia* are definite evidence of the presence of an early Franconia equivalent in this region. The four recorded genera favor reference to the *Elvinia* zone, although none of these species is sufficient to enable a clear distinction between the rather similar faunal assemblages characterizing the *Elvinia* zone and the overlying *Ptychopleurites* zone (*Irvingella* subzone of Wilson, 1949).

Aphelaspis *Zone.*—As mentioned above the record of an *Aphelaspis* fauna from the Little Rocky Mountains has proven to be erroneous and due to the misidentification in the field of the cranidia of a new genus. Actually this study has not revealed the presence of any member of the *Aphelaspis* fauna in any of the Little Rocky Mountains collections. Consequently, the fauna is not now known north of the Nixon Gulch section, though its presence is possible in the Yogo Gulch, Half Moon Pass and Lodge Pole Creek sections.

Crepicephalus *Zone Fauna.*—Two collections, B4 and B3, approximately 25 feet apart, comprise the only representation of this zone. As the collections contain several species in common, both are believed to represent the same faunal assemblage. All of the species have been previously described from nearby sections of central Montana, Wyoming and Alberta or from the Mississippi Valley. The faunal assemblage appears to be exactly the same as that representing the *Crepicephalus* zone in other central Montana sections, which had been termed (Lochman and Duncan, 1944, p. 33) a typical lower *Crepicephalus* faunule.

Cedaria *Zone Fauna.*—The faunal assemblages representing this zone appear to be assignable to two of the subzones recognized in the central Montana sections. Most of the collections are characterized by an abundance of *Arapahoia* species and individual specimens, and are readily referable to the middle *Cedaria* subzone. The assemblage in collections A1 and A2 from Sipary Ann Butte has *Armonia lata* (Howell and Duncan) and *Cedarina cordillerae* (Howell and Duncan) associated with the new genus, *Knechtelia*, which is also known to occur in the uppermost faunas of the Middle Cambrian Park formation. *Kormagnostus esterius* Lochman has too long a range to be significant. This assemblage is tentatively referred to the base of the lower *Cedaria* subzone. It is quite possible, however, that a larger collection would indicate a greater preponderance of Middle Cambrian forms. As is shown in the Half Moon Pass section, the Middle-Upper Cambrian boundary throughout central Montana is both lithologically and faunally transitional

in nature, and assignment of such a transitional faunule will necessarily be arbitrary.

SYSTEMATIC PALEONTOLOGY

All types are deposited at the U. S. National Museum, Washington, D.C.

cf. Lower *Dikelocephalus* Zone Fauna
PLETHOMETOPUS ALBERTENSIS Resser
Plate 46, figures 1–7

Plethometopus albertensis RESSER, 1942, Smithson. Misc. Coll., vol. 103, no. 5, p. 47, pl. 12, fig. 13.

Original description.—A single cranidium, typical of the genus in all respects is sufficiently well preserved to warrant naming. The simple large glabella, indicated by a faint dorsal furrow, is about three-fourths the length of the head, and tapers slightly to a rounded anterior margin. A strong occipital furrow separates a neck ring that extends into a short blunt spine. Fixigenes narrow, measuring at the eyes about a fifth the glabellar width. The posterolateral limbs are small and possibly short. Eyes small, situated about the midpoint of the glabella. In cross section the cranidium is rather evenly curved, while longitudinally the curvature is much greater, particularly in the anterior half. As a result the simple brim is convex in both directions. A faint broad anterior furrow is visible in the anterior angles.

Supplementary description.—Free cheek narrowly elongate, with small eye at inner angle; ocular platform narrow, increasing slightly posteriorly, flat, slightly downsloping; no marginal furrow; border narrow, slightly convex and downcurved with a medium-length anterior projection and a very short, slender genal spine. Facial suture cutting anterior margin half way out from center, curving outward, then round and running diagonally into and around palpebral lobes; thence curving rapidly out and back to cut posterior margin well in from genal angle.

Pygidium small, short, somewhat transverse; axis strongly convex, tapered posteriorly where it drops down steeply to the very narrow posterior border; divided by faint furrows into two segments and a terminal portion; dorsal furrow narrow, only at sides; pleural platforms triangular, three-fourths width of axis, moderately convex, divided by interpleural grooves into two segments which are crossed by broad shallow pleural furrows; no marginal furrow; no distinguishable border at sides.

Remarks.—About six cranidia, which average 1–2 mm. smaller than the holotype, several associated free cheeks and pygidia can be referred to this species. One cranidium in the collection is unpeeled and shows no dorsal or marginal furrows. The others are like the holotype, indicating that the well-defined dorsal furrow is on the inner surface only. All the specimens occur in limestone and are fairly well preserved although most of the cranidia appear to have been somewhat flattened. The species occurs in Alberta associated with *Ellipsocephaloides*, a genus which appears in Wisconsin and Minnesota in the *Ptychaspis-Prosaukia* zone and seems to characterize the upper half of the Franconian. In Montana the specimens occur by themselves in beds approximately 82 feet above the shales carrying a well-defined *Ptychaspis-Prosaukia* zone. As this is the highest species which has been obtained from the Cambrian section of this region, it is not possible to state exactly whether it still belongs within the *Ptychaspis-Prosaukia* zone or whether it should be considered somewhat later in age—the lower *Dikelocephalus* zone.

Formation and Locality.—Upper Cambrian, Pilgrim formation, coll. B12.

PROTOSPONGIA? sp. undet.
Plate 46, figure 18

On two small slabs of platy limestone a large number of sponge spicules were found scattered over and embedded in the clay film coating one of the surfaces of the slabs. The spicules show the characteristic cruciform shape as they lie in the clay, but closer inspection reveals that they are actually hexaxial spicules, and each center of the cross shows a break where the protruding ray has been broken or weathered off. If great care is taken the spicule can be removed from the clay and the opposite ray from the center can be seen. Apparently this mass of spicules represents the fortuituous preservation of the spicules of one or more individual sponges, since long slender monaxons as well as the more numerous hexaxons are present in the debris.

The spicules are tentatively referred to *Protospongia* as this is the only described sponge genus to which similar appearing spicules have been ascribed.

Formation and locality.—Upper Cambrian, Pilgrim formation, coll. B11.

Ptychaspis-Prosaukia Zone Fauna
IDAHOIA WISCONSENSIS (Owen)
Plate 46, figures 11–13

Crepicephalus? wisconsensis OWEN, 1852, Rep. Geol. Surv. Wisc., Iowa and Minn., Tab. 1, fig. 13, named and figured.
Conocephalites wisconsensis (Owen) HALL, 1863, 16th Rept. Cab. Nat. Hist. New York, p. 164, pl. 7, figs. 39–41, pl. 8, figs. 22–24, 27, 28.
Lonchocephalus wisconsinensis (Owen) MILLER, 1889, N. A. Geol. and Pal., p. 555.
Saratogia wisconsensis (Owen) WALCOTT, 1916, Smithson. Misc. Coll., vol. 64, no. 3, p. 198, pl. 34, figs. 5–5c (for complete synonymy).
Idahoia wisconsinensis (Hall) RESSER, 1935, Smithson, Misc. Coll., vol. 93, no. 5, p. 35.
Idahoia wisconsensis (Owen) SHIMER and SHROCK, 1944, Index Fossils of N. Am., p. 625, pl. 265, fig. 17.

First description (*Hall, 1863*).—Head large. Glabella strong, truncato-conical, moderately convex, sometimes subangular in the middle, width at base nearly equal to the length; front usually straight, sometimes a little curved; sides nearly straight and regularly converging: the posterior glabellar furrow oblique, and faintly marked; the middle one less distinct; the anterior one sometimes obscurely indicated near the anterior extremity of the glabella. Occipital furrow strongly impressed at the sides, but often faintly marked or scarcely perceptible in the middle. Occipital ring narrow at the sides, wider and inclining backwards in the middle, and rising to the base of a strong elevated spine, which is directed obliquely backwards, and in the course of its length is gently curved. Dorsal furrow well defined, not deep, a little more strongly impressed at the anterior angles of the glabella, and continued in front of the same strength as at the sides.

Facial suture curving slightly outwards from the frontal margin, and then gently curving towards the glabella at the anterior angle of the palpebral lobe, which is a little forward of the middle glabellar furrow; thence curving to the base of the eye, it is directed outwards.

Fixed cheeks narrow, with a narrow posterior limb; the palpebral lobe limited by a distinct groove: frontal limb much extended, and gently curving at the sides; the anterior border, for about one-third or nearly one-half its entire length, longitudinally flattened and ascending to the anterior margin, with a wide shallow furrow between it and the posterior gently convex portion of the limb. The shallow frontal furrow and posterior part of the limb are sometimes visibly striated, with flexuous interrupted lines which converge towards the glabella; and the bottom of the groove, in the cast, is sometimes marked by a row of granules or minute tubercles.

Remarks.—Four incomplete cranidia and two free cheeks occur in the shales of several collections. The cranidia are medium size, but one cheek reaches fairly large size as is to be expected in this genus. In spite of their fragmentary condition and some distortion the cranidia agree in every proportion with the types from Wisconsin. The brim is nearly twice the width of the border, is convex and downsloping whereas the border is flat, but still downsloping. Two pairs of glabellar furrows show up well, and one cranidium has a complete occipital spine which equals again the length of the cranidium alone.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Ptychaspis-Prosaukia* zone, colls. B8, B10.

MONOCHEILUS sp. undet.
Plate 46, figures 8–10

Remarks.—In two of the collections there occur several free cheeks of the very distinctive type associated with *Monocheilus anatinus* (Hall), the genotype from Wisconsin. Because of the peculiar structure the generic determination of these free cheeks is considered reasonably certain, but no specific determination can be made without a cranidium.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Ptychaspis-Prosaukia* zone, colls. B8, B10.

PSEUDAGNOSTUS JOSEPHA (Hall)
Plate 46, figure 14

Agnostus josepha HALL, 1863, 16th Ann. Rept. Cab. Nat. Hist. New York, p. 178, pl. 6, figs. 54, 55.
Pseudagnostus josepha (Hall) KOBAYASHI, 1935, Imp. Univ. Tokyo, Sec. II, vol. 4, pt. 2, p. 108; 1939, Imp. Univ. Tokyo, Sec. II, vol. 5, pt. 5, p. 157.
Pseudagnostus josepha (Hall) SHIMER and SHROCK, 1944, Index Fossils of N. Am., p. 601, pl. 251, figs. 5, 6.

Original description.—Head semi-elliptical, a little wider than long; the sides usually curving, sometimes straight for a part of their length, margined by a flattened or concave narrow limb; rather abruptly convex at the sides: the posterior margin, just within the angles, is produced on each side into a short spine.

Glabella prominent, narrow, extending about two-thirds the length of the head, and crossed by a shallow furrow near its anterior end: the posterior lobe is marked by an oblique furrow on each side, and a small node on the summit at the anterior termination. The triangular space on each

side, between the transverse and oblique furrows, is likewise elevated into a low node. The posterior central portion is gibbous, narrowed at the base, with a small tubercle on each side. A narrow longitudinal furrow extends from the apex of the glabella to the marginal limb.

Pygidium of the same form as the head, or a little wider: axis prominent, subquadrangular, wider than long, nearly one-third the length of the pygidium, bearing a node or short spine on its posterior extremity; sides and body of the pygidium (outside of the axis) highly convex.

Remarks.—Two fragmentary cephala are referred to this species. Though the preservation is poor, the presence of lateral spines at the posterior margin, a median furrow in front of the glabella and a strong median spine on the glabella, all indicate this species. *Pseudagnostus josepha* (Hall) is a rather important fossil of the *Ptychaspis-Prosaukia* zone, as it is widespread in this zone throughout the Cordilleran region.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Ptychaspis-Prosaukia* zone, colls. B9, B10.

PTYCHASPIS STRIATA Whitfield
Plate 47, figures 1–5

Ptychaspis granulosa HALL (part), 1863, 16th Ann. Rpt. Cab. Nat. Hist. New York, p. 173, pl. 6, figs. 33–40.

Ptychaspis striata WHITFIELD, 1878, Ann. Rpt. Geol. Sur. Wisc., p. 55; 1882, Geol. Surv. Wisc., vol. 4, p. 186.

Ptychaspis striata Whitfield, MILLER, 1889, N. A. Geol. and Pal., p. 564.

Ptychaspis striata Whitfield, SHIMER and SHROCK, 1944, Index Fossils of N. America, p. 631, pl. 262, fig. 2.

Original description.—Differs from *Ptychaspis granulosa* Owen sp. in having the surface of the head strongly striated or marked with elevated ridges, which are more or less parallel to the margin.

Remarks.—From the shales of two collections a small number of cranidia, free cheeks and pygidia have been obtained. The specimens, though crushed and fragmentary, are in every feature characteristic of the species. The cranidium is crossed by very coarse imbricating ridges which are particularly prominent on the fixed cheeks, the border and the anterior lobe of the glabella. On the free cheeks the strong ridges run parallel to the margin on the border, the genal spine and the outer half of the ocular platform, while the inner half of the ocular platform is marked by very coarse granules.

In Wisconsin and Minnesota this species occurs in the middle third of the *Ptychaspis-Prosaukia* zone.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Ptychaspis-Prosaukia* zone, colls. B8, B10.

WILBERNIA EXPLANATA (Whitfield)
Plate 46, figures 15–17

Conocephalites (Ptychaspis) explanatus WHITFIELD, 1880, Ann. Rep. for 1879, Wisc. Geol. Surv., p. 49; 1882, Geol. Wisconsin, vol. 4, p. 181, pl. 1, figs. 27, 28.

Ptychoparia explanata (Whitfield) MILLER, 1889, N. A. Geol. and Pal., p. 565.

Idahoia explanata (Whitfield) RESSER, 1937, Smithson. Misc. Coll., vol. 95, no. 22, p. 14.

Original description.—Species known only by the glabella and fixed cheeks, and these in a somewhat fragmentary condition. The form of these parts, as seen united, is somewhat quadrangular, rather longer than wide, and with rather prominent surface features. The glabella is elongate-quadrangular, narrowest across the anterior third of its length, rounded anteriorly and widening posteriorly to the back of the occipital ring; its length, when measured from the occipital furrow, is equal to once and a half the smallest transverse diameter; surface moderately convex and marked by three pairs of transverse furrows, the middle one of which is a little anterior to the middle of the length, deeply marked near the outer ends, and barely perceptible on the inner third of the length, their direction being slightly backwards toward the center. The posterior pair is very oblique, equally well marked, but narrower, and extends entirely across the glabella, but only faintly marked in the center. The anterior pair is short, more faintly marked, and situated about one-fourth of the width of the glabella from the anterior end. Fixed cheeks and frontal limb proportionally wide, the anterior half of the latter bent upward, forming considerable of an angle with the flattened portion around the glabella. Palpebral lobes proportionally large and moderately prominent; ocular ridges very distinctly marked, and very oblique, arising from the posterior part of the anterior glabellar lobe, and passing to the anterior extremity of the eye lobe. Occipital ring flattened or very depressed convex on the surface, narrower than the glabellar lobes, and the furrows shallow and only moderately well marked. Facial suture passing from the eye with a strong outward curvature to the anterior border, which it reaches nearly on a line with the eye; its course behind the eye not determined. Surface apparently smooth.

Remarks.—Examination of the holotype cranidium of this species at the University of Wisconsin indicates clearly that the species belongs in the genus *Wilbernia* rather than *Idahoia*. A diagnosis of generic characters of each of the genera is given below. It

will be noted from this analysis that in the structure of the cranidia the two genera have many features in common but do differ in items 1, 3 and 6 and in the structure of the associated pygidia. *Wilbernia* appears surely in the *Conaspis* zone, possibly earlier, and ranges through the greater part of the Franconian, while *Idahoia* is prominent in the upper half of the stage.

Diagnosis of *Wilbernia*

Cranidium: 1) palpebral lobes medium size, situated a short distance back of midline of glabella.

2) glabella subrectangular with rounded front corners; convexity low, flat for two-thirds the way forward, then curving down rapidly in front; two to three pairs of short glabellar furrows.

3) fixed cheeks one-third width of glabella, measured without palpebral lobes.

4) fixed cheeks flat, horizontal.

5) posterior limb slightly more than two-thirds width of occipital ring.

6) brim very variable in width, marginal furrow with alternating fine pits and elevations, border about medium.

Pygidium: 1) broadly transverse; axis medium width, convex.

2) border somewhat less than one-half length of pygidium, concave.

Diagnosis of *Idahoia*

Cranidium: 1) palpebral lobes medium size, on midline of glabella.

2) glabella broadly conical with nearly straight front; convexity regular, fairly low; two pairs of very weak furrows.

3) fixed cheeks one-fourth width of glabella, measured without palpebral lobes.

4) fixed cheeks flat, horizontal.

5) posterior limbs narrow, two-thirds width of occipital ring.

6) brim with or without row of pits at front, marginal furrow, border.

Pygidium: 1) transversely elongate; axis of medium width, tapered.

2) border one-half length of pygidium, variable in slope.

Five cranidia are referred to this species, one as large as the holotype and the others somewhat smaller. They agree perfectly in every proportion with the holotype, except that as these specimens are all flat shale casts it is impossible to determine whether the border was originally upturned as it is in the holotype. The species appears to occupy approximately the same horizon in both regions as it is a member of the *Ptychaspis-Prosaukia* zone in the Montana section.

Formation and Locality.—Upper Cambrian, Pilgrim formation, *Ptychaspis-Prosaukia* zone, colls. B9, B10.

Conaspis Zone Fauna

MAUSTONIA Raasch 1939

Genotype—*Maustonia nasuta* (Hall)

As the characteristics of *Maustonia* have never been discussed, I am giving a diagnosis of the genus below, based upon the characters of the genotype. The genus appears to be a geographically widespread member of the *Conaspis* zone and is represented by a number of species. Recent studies have indicated that it is not related to the *Conaspis* stock.

Cranidium: 1) palpebral lobes under medium-size, almost small, situated on anterior one-third line of glabella.

2) glabella conical, tapered, with rounded corners and straight on median line; convexity low, regular; three pairs of diagonal furrows, posterior pair long but not quite meeting in center; small median occipital node.

3) fixed cheeks practically one-fourth width of glabella at midline.

4) fixed cheeks horizontal to very slightly upsloping.

5) posterior limbs not quite same width as occipital ring.

6) brim of variable width, marginal furrow, border of variable width with a usual increase on the median line, giving a more or less nasute appearance.

Pygidium: 1) moderately transverse; axis well-defined, convex, tapering nearly to posterior margin.

2) border narrow, with 0–3 pairs of marginal spines, which may be extremely small in size.

MAUSTONIA CORDILLERENSIS
Lochman, n. sp.
Plate 47, figures 6–13

Cranidium oblong with prominent posterior limbs; glabella conical, tapered forward

with anterior corners rounded and front tending to be straight, length equal to width at base; convexity low, regular; three pairs of diagonal glabellar furrows, first pair short, faint, second well-defined, third strong and long, not quite meeting at center; dorsal furrow narrow, well-defined along sides and front corners, becoming fainter across median line; occipital furrow of medium width, well-defined; occipital ring of medium width, flat, with a small median node; brim and border same width, brim increasing in width laterally, flat, very slightly downsloping; marginal furrow of medium width, shallow; border decreasing a bit in width laterally, slightly convex, horizontal; anterior margin bluntly pointed. Fixed cheeks not quite one-fourth width of glabella on midline, slightly convex, nearly horizontal; palpebral lobe under medium-size, arcuate; palpebral furrow narrow, shallow; a very faint ocular ridge; posterior limbs triangular, almost same width as occipital ring, crossed by a narrow, well-defined marginal furrow. Free cheek narrow, triangular with eye at inner angle; ocular platform of medium width, convex, gently downsloping; marginal furrow narrow, well-defined except at posterior corner; border narrow, slightly convex, horizontal with slender pointed anterior projection and a long slender genal spine. Facial suture cutting anterior margin approximately on a line with dorsal furrow, curving out to marginal furrow, then in to and around palpebral lobes; thence running diagonally outward and curving back abruptly to cut posterior margin well within genal angle.

Fragment of a thoracic segment shows a median pleural furrow and a slender medium length end spine.

Pygidium transverse, nearly twice as wide as long; axis of medium width, convex, tapering to a rounded end and reaching almost full length of pygidium, divided by broad deep furrows into three segments and a narrow terminal portion; dorsal furrow narrow, shallow, outlining only sides clearly; pleural platform approximately two-thirds width of axis, horizontal, slightly convex, divided by broad, deep interpleural grooves into four segments, two median ones crossed by a shallow narrow pleural furrow; marginal furrow very narrow, obsolete anteriorly, faint posteriorly; a narrow, rim-like border; one pair of anterior marginal spines appear on the larger pygidia as very short blunt projections opposite the anterior interpleural grooves.

Outer surface smooth; inner surface apparently smooth, with weak venations crossing the brim and ocular platform.

Remarks.—The several cranidia, free cheeks and pygidia were obtained from a loose piece which consisted simply of a coquina of the parts of this one species. Most of the specimens are complete in outline, though the preservation of the surface of the test is not too good. A number of undescribed species occurs in the Franconia of Wisconsin and show in the associated pygidia the range in numbers of pairs of spines on the pygidium. The gradual development of a short pair in the Montana species suggests that we are observing the inception of spines on the pygidium, but until the Wisconsin species are described and their stratigraphic position indicated it is impossible to draw any definite conclusions.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Conaspis* zone, coll. E3.

Elvinia Zone Fauna

BERKEIA OCCIDENTALIS

Lochman, n. sp.

Plate 48, figures 1–10

Cranidium subquadrate; glabella broadly conical, front only slightly rounded; convexity apparently moderate and regular; three pairs of glabellar furrows, first pair very short and faint, second pair longer, slanted, posterior pair arcuate; dorsal furrow narrow, well-defined; occipital furrow narrow, deep; occipital ring moderately convex, triangular in shape with a short flat median spine; brim of medium width (2½ times width of border), convex, downsloping; marginal furrow narrow, well-defined; border narrow with median expansion, slightly convex, horizontal; anterior margin regularly curved. Fixed cheek slightly less than one-half width of glabella, moderately convex, horizontal; palpebral lobes medium-sized, arcuate, very slightly back of midline of glabella; palpebral furrow narrow, well-defined; ocular ridge narrow, faint, diagonal to front of glabella; posterior limb slightly

shorter than occipital ring, crossed by a broad deep marginal furrow. Free cheek triangular with medium eye at inner angle; ocular platform of medium width, convex, downsloping; marginal furrow narrow, well-defined; border narrow, slightly convex, horizontal, with a long pointed anterior projection and a long slender genal spine. Facial suture cutting anterior margin on line with dorsal furrow, curving out to marginal furrow, then outward and back in to and around palpebral lobes; thence curving outward and backward to cut posterior margin well within genal angle.

Thorax not known.

Pygidium narrowly transverse, width slightly over twice length; axis of medium width, moderately convex, extending nearly full length of pygidium, tapering slightly, divided into three segments and a short terminal portion by well-defined furrows; dorsal furrow well-defined along sides only; pleural platforms narrower than axis, triangular, low, divided into three broad segments by shallow interpleural grooves; faint pleural furrows may be present; no marginal furrow observed; a very narrow border may be present.

Outer surface may be finely granulated; inner surface not known.

Remarks.—This species is represented in the material of collection B7 by a great many shale impressions of cranidia, as well as several associated free cheeks and pygidia. It is unfortunate that most of the specimens are not more than 2 mm. in length. The several larger cranidia are all fragmentary. Moreover, the shale preservation makes it difficult to determine convexity, though several of the larger fragments do give some idea of the normal condition.

The pygidium appears to be identical with that assigned to the genotype, *B. typica* Resser. In the cranidium it is also similar to this species and the other valid species, *B. saratogensis* Resser, but differs from both of them in the narrower proportions of the brim and in the occipital spine.

This species occurs with *Pterocephalia bridgei* Resser in the Lodge Pole Creek section, and while I was studying the types of the latter species from Flat River, Missouri, I observed cranidia of this species of *Berkeia* on the same pieces of limestone.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Elvinia* zone, coll. B7,

ELVINIA ROEMERI (Shumard)
Plate 47, figures 21–23

Dikelocephalus roemeri SHUMARD, 1861, Am. Jour. Sci., 2nd ser., vol. 32, p. 220.

Dicellocephalus roemeri Shumard, MILLER, 1889, N. A. Geol. and Pal., p. 544.

Ptychoparia roemeri (Shumard) WALCOTT, 1914, Smithson. Misc. Coll., vol. 57, no. 13, p. 352.

Elvinia roemeri (Shumard) WALCOTT, 1924, Smithson, Misc. Coll., vol. 75, no. 2, p. 56, pl. 11, fig. 3; 1925, Smithson. Misc. Coll., vol. 75, no. 3, p. 88, pl. 17, figs. 9–13.

Elvinia roemeri (Shumard) BRIDGE, 1937, U. S. Geol. Survey Prof. Paper 186-M, p. 251, pl. 67, figs. 2a, b, 3a, b; pl. 69, figs. 1–22 (for complete synonomy).

Elvinia roemeri (Shumard) RESSER, 1938, Smithson. Misc. Col., vol. 97, no. 10, p. 29.

Elvinia roemeri (Shumard) SHIMER and SHROCK, 1944, Index Fossils of N. America, p. 625, pl. 264, figs. 34–37.

Elvinia roemeri (Shumard) FREDERICKSON, 1949, Jour. Paleontology, vol. 23, no. 4, p. 352, pl. 69, figs. 19–21 (for complete synonymy).

Original description. The cephalon is elevated, semicircular in section, the anterior end with a broad, abruptly deflected border. The posterior end is bordered by an occipital ring which is set off by a well-marked occipital furrow. The glabella is bounded on all sides by a distinct furrow and rises to the same height as the fixed cheeks. It shows two faint, slanting glabellar furrows on each side. The course of the facial suture—in other words, the lateral edges of the cranidium—is not as plainly shown in the examples before me as in the illustration. However, one can readily see that in general it agrees with the facial suture in the genus *Calymene* in that the two lines are widely separated from each other at the anterior end and run in an oblique direction to the posterior corners of the cephalon. The free cheeks are missing in all known specimens. . . . No thoracic segments which might belong to this cranidium and pygidium are known. The relationship of the parts which have been described to other trilobite genera is not clear. The cephalon, on the one hand shows a few similarities in structure with *Calymene*, but the pygidium, on the other hand, shows an entirely different type of structure.

This pygidium is almost semicircular, arched, bordered by an upturned rim. The axis is thick and broad and is raised in the form of a hemicylinder high above the lateral sides of the shield. The width and height remain the same to the posterior margin of the shield, where it is abruptly truncated. The axis, aside from the anterior bordering ring, shows four annulations, the last one of which is more or less divided into two parts by a depression. Only the three anterior rings continue on to the strongly arched sides as broad, flattened pleurae.

The outstanding character of this pygidium is the thick axis, which maintains the same width throughout its length. The flattened, short pleurae indicate affinities with certain trilobite genera such as *Ceraurus* Green (*Cheirurus* Beyrich) and particularly *Sphaerexochus* Beyrich. However, in these last-named genera the outer margin is serrate, while in this specimen it is entire and plainly rounded.

Remarks.—One medium-sized cranidium of which the outline is nearly complete but from which most of the test has been broken, and one fragmentary free cheek represent this species. Its presence is most important in showing not only the widespread range of *Elvinia roemeri* (Shumard) but also as definite evidence of the *Elvinia* zone in this region.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Elvinia* zone, Coll. E2.

PTEROCEPHALIA BRIDGEI Resser
Plate 47, figures 14–18

Pterocephalia sanctisabae BRIDGE (part) 1937, U. S. Geol. Survey Prof. Paper 186-M, p. 246, pl. 68, figs. 25, 26.
Pterocephalia bridgei RESSER, 1938, Smithson. Misc. Coll., vol. 97, no. 10, p. 40.
Pterocephalia oriens RESSER, 1938, Smithson. Misc. Coll., vol. 97, no. 10, p. 40.
Pterocephalia potosiensis RESSER, 1938, Smithson. Misc. Coll., vol. 97, no. 10, p. 40.

Original description.—This species is characterized by a wide brim, a relatively long glabella, and the curved course of the anterior facial suture. The pygidium assigned to the species has a narrower border than *P. sanctisabae*, and its rear margin is notched. The surface of the cranidium behind the eyelines and on the glabella, is nearly smooth. Anterior to these parts the irregular longitudinal folds are rather heavy, and the surface is marked by the usual horizontal, anastomosing lines.

Remarks.—In determining the specific assignment of the Montana species, all the specimens at the U. S. National Museum which had been measured and originally referred to *Pterocephalia sanctisabae* Roemer by Bridge and which were later broken up into a number of separate species by Resser were carefully examined. It was found that the three above cited species of Resser from Missouri were actually only specimens of one and the same species. This species I consider to be distinct from *P. sanctisabae* Roemer because all the specimens, in limestone, show the midlength of the preglabellar area (brim and border combined) to be only a small amount more than the midlength of the glabella and occipital ring. This is true for all cranidia of medium to large size, whereas in the small cranidia the midlength of preglabellar area and of glabella and occipital ring become the same. In *P. sanctisabae* Roemer the midlength of the preglabellar area is consistently once and a half the midlength of glabella and occipital ring. In spite of Resser's original description cited above, no other distinction in any feature of the cranidium or of the pygidium can be detected between the two species. The occurrence of this same distinction in shale cranidia from Montana, both medium-sized and small, strongly indicates that this distinction is a valid specific character. Enough specimens are available in the U. S. National Museum collections to show conclusively that size does not cause the observed variation in proportion.

Several cranidia, and pygidia and one hypostoma are referred to this species. As is usual in shale specimens, the imprint of the posterior edge of the doublure shows up rather strongly on the brim of the cranidium, but it should not be mistaken for the marginal furrow which is obsolete in this genus.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Elvinia* zone, coll. B7.

cf. BURNETIA sp.
Plate 47, figure 19

One fragment of a medium sized trilobite cranidium consists of a portion of the glabella, a very narrow brim and a wide concave border. As this type of preglabellar area is very characteristic of *Burnetia*, a genus which is associated with *Elvinia*, the generic identification is believed to be quite reasonably certain.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Elvinia* zone, coll. E2.

IDDINGSIA? sp. undet.
Plate 47, figure 20

A single crushed and incomplete cranidium from the *Elvinia* zone of collection B7 is figured for reference but not described. The preservation of the single specimen certainly does not warrant description as a

new species, although the features preserved strongly suggest that the form may represent a new species which could be ancestral to the three closely related genera, *Burnetia*, *Iddingsia* and *Dokimocephalus*. The following features appear to constitute the generic distinctions between the cranidia of the three genera: In *Iddingsia* the glabella is broadly conical with a tendency to straighten across the front, the posterior two pairs of glabellar furrows are deeply impressed, the glabella has moderate to strong convexity, an ocular ridge is present, the fixed cheeks are definitely upsloping, and on all described species the brim is the same width or only slightly less that of the border.

In *Burnetia* the glabella is broadly conical with well rounded front, tumid, only posterior pair of glabellar furrows impressed, position of the other two pairs is indicated by the absence of granules, weak to obsolete ocular ridge, the fixed cheeks downsloping, and on all described species the brim is very narrow, the border much wider and concave in profile.

In *Dokimocephalus* the glabella follows the *Iddingsia* pattern, but the second pair of glabellar furrows is less deeply impressed, an ocular ridge is present, the fixed cheeks are approximately horizontal in position, and on all described species the brim is narrow and the border exaggeratedly prolonged.

This Montana cranidium appears to have, when allowance is made for the crushing, a glabellar structure like that of *Iddingsia* and a flat, medium-wide border, but the brim is very narrow on the median line, suggestive of *Burnetia*. The specimen is a poorly preserved shale cast, so that depth of furrows and presence of ocular ridge and ornamentation are difficult to judge.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Elvinia* zone, coll. B7.

Crepicephalus Zone Fauna

"AGNOSTUS" sp. undet.

Plate 48, figure 21

Remarks.—A single *Agnostus* cephalon was obtained from the shales of B3. Although slightly crushed it is preserved as a thin calcite film over the shale mold and its characters are readily distinguishable. It is, however, the general type of cephalon which occurs in several agnostid genera to be found in the *Crepicephalus* zone, so that until a pygidium can be associated with it, no accurate generic or specific determination can be undertaken.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Crepicephalus* zone, coll. B3.

COOSIA ALBERTENSIS Resser

Plate 49, figures 13–21

Coosia albertensis RESSER, 1942, Smithson. Misc. Coll., vol. 103, no. 5, p. 73, pl. 13, figs. 25–28.

Original description.—Although apparently an abundant species, only a few specimens have been segregated in the collection. This is not a large species, but is typical of the genus. The glabella tapers to a rounded front. A keel is clearly defined and faint shadows indicate glabellar furrows. Brim, one-third the length of the glabella, has a more clearly defined rim than usual. The fixigenes are narrow and the palpebral lobes rather large.

In the pygidium the axis, with fairly deep furrows, occupies about half the pygidial length. The pleural lobes slope down rather gently to the wide border which assumes a horizontal position.

Supplementary description.—Cranidium, elongate, length somewhat greater than width; glabella conical, tapered slightly with broadly rounded front, convexity low; dorsal furrow broad, shallow, faint on outer surface but well defined on inner; occipital furrow very faint on outer surface, broad and clear on inner; occipital ring of medium width, flat; brim narrow, flat, slightly downsloping; marginal furrow broad, very shallow; border slightly wider than brim, very slightly convex, horizontal; anterior margin curved. Fixed cheeks very narrow, flat, slightly upsloping; palpebral lobe of medium size, crescentiform, situated very slightly back of midline of glabella; palpebral furrow broad, shallow, on inner surface only; no ocular ridge apparent; posterior limb narrow, length just over one-half that of occipital ring; crossed by a faint shallow marginal furrow on outer surface. Free cheek rectangular in outline, with medium-sized eye at inner angle; ocular platform narrow anteriorly, expanding posteriorly, flat, sloping slightly downward; marginal furrow broad, shallow, fading out completely posteriorly; border slightly narrower than platform, slightly convex, horizontal, with

a short pointed anterior projection and a broadly rounded genal angle. Facial suture cutting anterior margin far out at sides, curving down to marginal furrow, then diagonally into and around palpebral lobes, thence running straight out, then curving back and down to cut posterior margin well within genal angle. Hypostome elongate-oblong; anterior lobe a moderately convex oval separated from convex crescentic posterior lobe by shallow furrows on sides; posterior border wide, bilobed, continuing laterally into a second set of lobes before narrowing into a rim which runs into the short flat pointed lappets; a broad shallow macula just within posterior lateral border.

Pygidium broadly transverse; axis slightly narrower than pleural platform, low regular convexity, just slightly more than one-half length of pygidium, divided into three segments and a short broad terminal portion by broad shallow furrows; dorsal furrow broad, shallow, absent around end; pleural platform of medium width, triangular, slightly downsloping, crossed by a single well-defined anterior interpleural groove; no pleural furrows; border of medium width, slightly concave, nearly horizontal in position, posterior border smoothly curved.

Outer surface of test smooth except for low imbricating ridges on border of cranidium, free cheek, pygidium and hypostome; inner surface of test covered with medium-sized punctae.

Remarks.—This species is abundantly represented in limestone lenses of a *Coosia* coquina, a common occurrence for specimens of this genus, but one which leads to difficulty in obtaining good specimens as it is hard to free the numerous specimens from each other. Only medium-sized cranidia and pygidia have been obtained which are fairly complete, but much larger fragments of all parts of the carapace occur.

The species is characterized by the broad short glabella and strong marginal furrow of the cranidium. The pygidium is very similar to other Montana species, differing only in being smoother and flatter.

Formation and Locality.—Upper Cambrian, Pilgrim formation, *Crepicephalus* zone, colls. B4 and B3.

COOSIA MODESTA Lochman
Plate 49, figures 11, 12

Coosia modesta LOCHMAN, 1944, Geol. Soc. America Sp. Paper 54, p. 48, pl. 6, figs. 1–6.

Original description.—Cranidium elongate with a broadly conical, slightly convex glabella; no trace of glabellar furrows; dorsal furrow narrow, shallow; occipital furrow broad, shallow; occipital ring of medium width, flat. Posterolateral limbs not known. Fixed cheeks slightly less than one-third width of glabella, slightly convex; palpebral lobes of medium size, crescentiform, situated just posterior to transverse median line of glabella; a low ocular ridge extending diagonally to dorsal furrow; frontal limb very narrow, flat, downsloping; transverse furrow of medium width, very shallow; frontal border three times the width of limb, slightly convex, horizontal; anterior margin

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EXPLANATION OF PLATE 48

FIGS. *1–10—Berkeia occidentalis* Lochman, n. sp. *1*, shale surface crowded with small cranidia and free cheeks, ×2; *2*, a larger pygidium, ×3; *3*, another shale surface with cranidia and free cheeks, one large and apparently having a granulated outer test, ×5; *4*, largest cranidium, ×2½; *5*, small cranidium with only border missing, ×3; *6*, shale mold of small pygidium, ×4; *7*, associated hypostome, ×4; *8*, a very small distorted pygidium with thin calcite film preserved, ×8½; *9*, a very small distorted cranidium with thin calcite film showing an occipital spine, ×10; *10*, the small holotype cranidium with an associated metaspid cephalon, ×5, all collection B7. (p. 332)

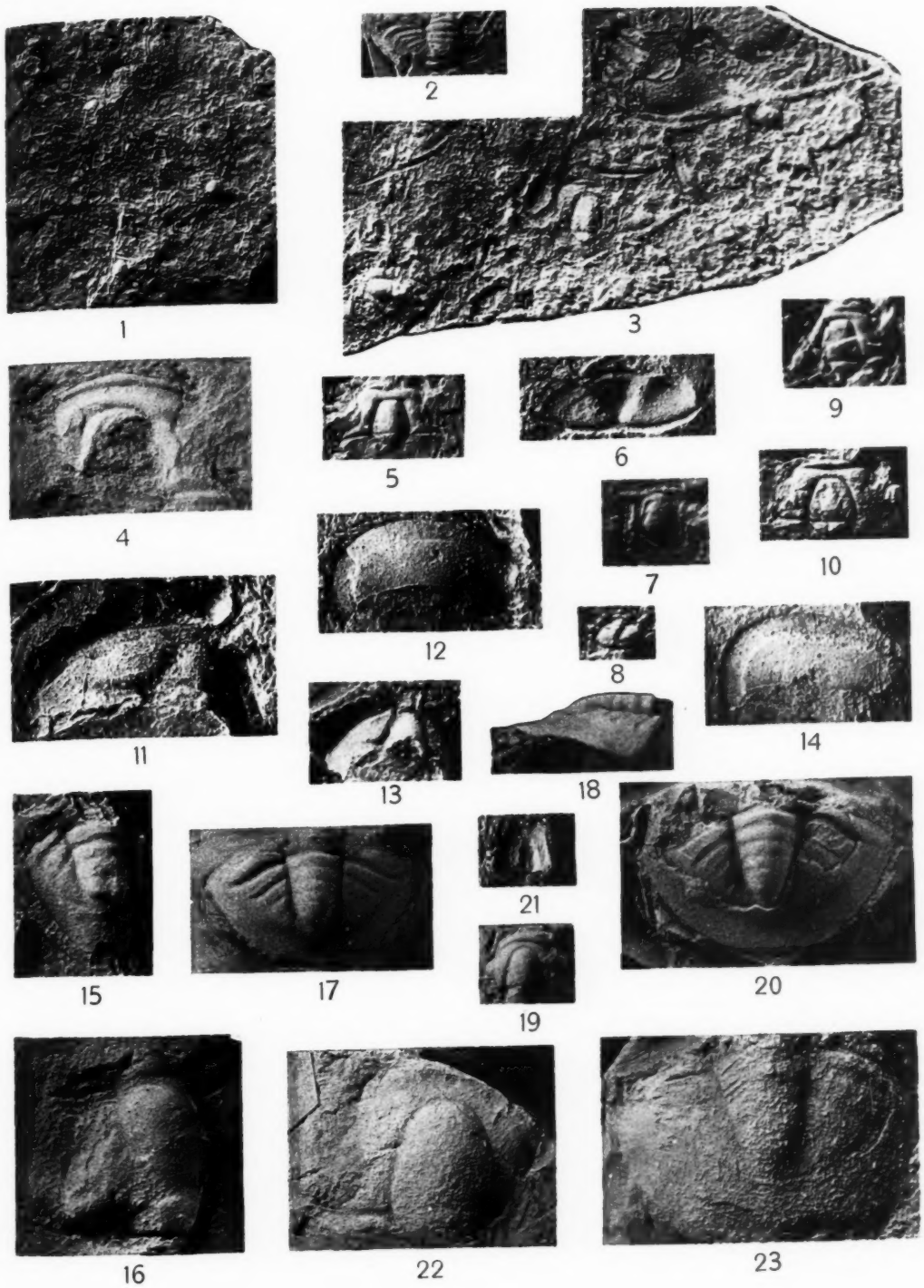
11–14—Dresbachia amata Walcott. *11*, large broken and distorted cranidium; *12*, a well-preserved free cheek; *13*, a small, more complete cranidium; *14*, shale cast of free cheek, all ×3, hypotypes, collection B3. (p. 338)

15, 16—Uncaspis aff. *U. unca* (Walcott). *15*, a complete but compressed pygidium; *16*, a broken and distorted cranidium, both ×3, collection B3. (p. 340)

17–20—Maryvillia violaensis Resser. *17*, dorsal view of complete, peeled pygidium, ×3; *18, 20*, side and dorsal views of large pygidium with some of outer surface, ×3; *19*, a very small, broken associated cranidium, ×4, hypotypes, collection B4. (p. 339)

21—"Agnostus" sp. A single crushed cephalon, ×3, collection B3. (p. 325)

22, 23—Maryvillia alberta Resser. Dorsal views of deeply weathered cranidium and largest of three associated pygidia all in single limestone nodule, ×2, ×1½, hypotypes, collection B3. (p. 339)



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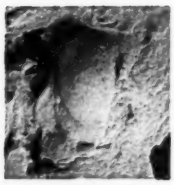
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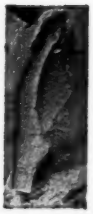
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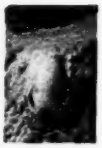
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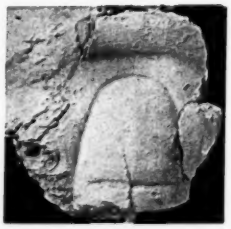
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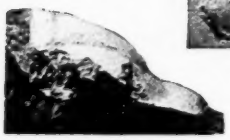
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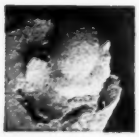
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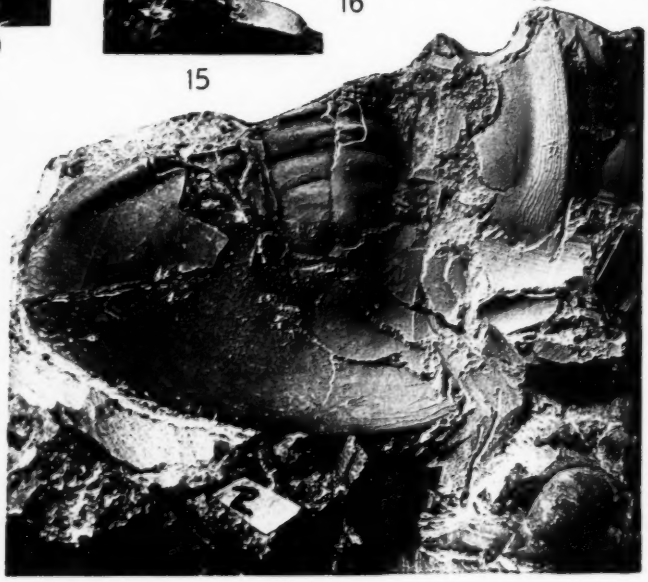
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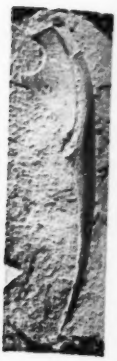

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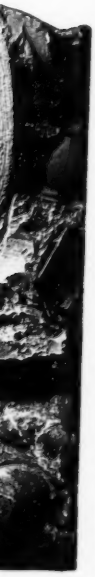

rounded. Free cheek elongate with large eye at inner angle; ocular platform narrow anteriorly, broadening posteriorly; marginal furrow broad, very shallow, sloping down to the moderately wide, flat marginal border; a very short, pointed genal spine.

Facial suture cutting margin on line with palpebral lobes, curving smoothly back and into and then around palpebral lobes; thence curving out and abruptly down to cut posterior margin well within genal angle.

Pygidium broadly transverse; axial lobe of medium width, strongly convex, slightly more than one-half length of pygidium, merging posteriorly into border, divided by broad, shallow furrows into three segments and a terminal section; pleural lobes one and a half width of axial, moderately convex, divided into three broad, backward sloping segments marked by faint pleural furrows; marginal border wide, slightly concave; in young forms a slight median inbending on posterior margin which is lost in adults.

Outer surface of test covered with low small granules, except the anterior of frontal limb, the frontal border and marginal border of cephalon and outer edge of marginal border of pygidium which are crossed by parallel, wavy, broken ridge; transverse furrow and marginal furrow of cephalon smooth; inner surface of test coarsely punctate.

Remarks.—Two small cranidia in limestone have been referred to this species. The largest, 5 mm. in length, is complete enough to make identification certain, but the smaller specimen, 3 mm. in length, has most of the border broken off so that it is difficult to determine either its convexity or proportions. However, the glabella appears to be more elongate, as in *Coosia modesta*, and so it also is tentatively assigned to this species.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Crepicephalus* zone, coll. B4.

CREPICEPHALUS BUTTSI MONTANENSIS
Lochman
Plate 49, figures 1–9

Crepicephalus buttsi RESSER, 1938, Geol. Soc. America, Sp. Paper 15, p. 72, pl. 11, figs. 28, 29, 49, 50.

Crepicephalus buttsi montanensis LOCHMAN, 1944, Geol. Soc. America, Sp. Paper 54, p. 58, pl. 7, figs. 29–32.

Crepicephalus buttsi Resser SHIMER and SHROCK, 1944, Index Fossils of N. America, p. 623, pl. 262, figs. 13–15.

Original description.—*C. buttsi* is a fairly large species characterized by the convex posterior margin and the outward direction of the pygidial spines. It is smooth, with moderately deep furrows.

Supplementary description.—Cranidium with a slightly convex, regularly conical glabella; three pairs of short shallow glabellar furrows; dorsal furrow narrow, well defined; occipital furrow moderately wide, deep at sides, shallow across mid-line; occipital ring of medium width, slightly convex. Posterolateral limbs long and slender with a deep broad intramarginal furrow. Fixed cheeks one-third width of glabella, nearly flat; palpebral lobes large, crescentiform, situated on transverse median line of glabella; palpebral furrow shallow, narrow; ocular ridge narrow, diagonal; frontal limb of medium width, slightly convex; transverse furrow narrow but well defined; frontal border same width as limb, convex; anterior margin slightly rounded. Free cheek not known.

Facial suture cutting anterior margin on line with palpebral lobes, curving out and then running diagonally into and curving around palpebral lobes; thence passing outward and backward to cut posterior margin within genal angle.

Pygidium broadly transverse, rectangular; axial lobe of medium width, strongly convex, extending two-thirds length of pygidium, tapering to a broadly rounded end, divided into three segments and a wide terminal portion by shallow furrows; pleural lobes same width as axial, slightly convex, divided into three broad segments crossed by faint pleural furrows; marginal border

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EXPLANATION OF PLATE 49

FIGS. *1–9*—*Crepicephalus buttsi montanensis* Lochman. *1*, pygidium with well preserved outer surface, ×2; *2*, *5*, dorsal and side views of a nearly complete cranidium with well preserved outer surface, ×2; *8*, pygidium showing nearly complete spines, ×1½; *9*, a very small associated hypostome, ×5, hypotypes all from collection B4. *3*, *7*, ventral and dorsal views of two associated free cheeks, ×2, ×1; *4*, shale cast of cranidium, ×2; *6*, shale mold of pygidium, ×2, hypotypes, collection B3. (p. 337)

10—*Holcacephalus* cf. *H. robustus* Lochman. A single very small broken cranidium, ×3, hypotype, collection B4. (p. 339)

11, *12*—*Coosia modesta* Lochman. *11*, a small, nearly complete cranidium, ×3; *12*, a very small cranidium, ×4, hypotypes, collection B4. (p. 336)

13–21—*Coosia albertensis* Resser. *13*, *16*, two broken hypostoma in shale, ×2, collection B3. *14*, *15*, dorsal and side views of broken cranidium, ×2; *17*, a partially broken free cheek, ×2; *18*, *19*, side and dorsal views of medium-sized, partially peeled pygidium, ×1; *20*, another broken cranidium, ×2; *21*, a piece of typical *Coosia albertensis* coquina, showing fragmentary cranidium, free cheek and large pygidium, ×2, hypotypes, collection B4. (p. 335)

of medium width, flat, merging at posterolateral corners into the bases of slender, moderately long, slightly curved spines, which diverge about 20° from parallel to lateral margin; posterior margin moderately curved.

Description of variety.—Cranidium identical in all features with that of the species; pygidium identical in shape of body part and in shape, size, and curvature of spines; the posterior marginal border is narrower than in *C. buttsi* Resser, giving a proportional length ratio with the axial lobe of nearly 1:3 rather than 1:2 as in the species; the posterior margin is only very slightly curved.

Remarks.—A number of cranidia, pygidia, free cheeks and a few hypostoma have been referred to this species. The specimens occur both in shales, and in limestone lenses and nodules within the shales. The two occurrences afford an accurate means of comparing the effects of different preservation upon appearance. In the shale specimens the full length of the spines is frequently present indicating that they are over twice or nearly three times the length of the body of the pygidium. Also in the shale pygidia the posterior margin has been slightly curled under, giving in some specimens a concave outline. The shale cranidia are all flattened whereas the limestone specimens give the true profile, but the proportions of parts do not vary in the two. The limestone specimens show the outer surface of the test to be covered by rather distinctive flat granules or ripples, with the positions of the glabellar furrows smooth, and all the borders crossed by long, narrow imbricating ridges running roughly parallel to the margin. One small pygidium retains two of the posterior thoracic segments.

The occurrence of these cranidia and pygidia together in a third locality rather definitely substantiated their association as a single species. I have recently observed this same species in undescribed material from Wisconsin.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Crepicephalus* zone, colls. B3, B4.

DRESBACHIA AMATA Walcott
Plate 48, figures 11–14

Dresbachia amata WALCOTT, 1916, Smithson. Misc. Coll., vol. 64, no. 3, p. 167, pl. 26, figs. 5, 5a–c.

Dresbachia appalachia RESSER, 1938, Geol. Soc. America, Sp. Paper 15, p. 74, pl. 10, figs. 32–34.

Dresbachia amata Walcott SHIMER and SHROCK, 1944, Index Fossils of N. America, p. 623, pl. 264, fig. 22.

Original description.—General form of cephalon transversely crescentic; the posterior margin arching forward from the lateral margins, strongly convex. Glabella subtriangular in outline and marked by three pairs of oblique, short, deep lateral furrows; occipital ring strong and sharply defined by a narrow, deep occipital furrow. The frontal limb and border appear to be represented by a narrow projection in front of the glabella that has a deep longitudinal furrow which terminates at a narrow frontal rim. The sides of the furrow appear as though the test had been folded downward, leaving only a narrow strip at the top next to the facial suture.

On a small cranidium 1 mm. in length the frontal border projects very much as in *Proampyx acuminatum* (Angelin), but, unlike the nasute projection of the latter species, it has a longitudinal furrow that extends forward from in front of the glabella, which is the beginning of the deep furrow present on cranidia 3 to 5 mm. in length.

Fixed cheeks large, elongate, and arched backward; a strong intramarginal furrow extends from the dorsal furrow beside the glabella out on the cheek, where it fades away before reaching the outer margin. The palpebral lobe has not been seen; it is probably situated by the side of the narrow projection in front of the glabella or else is very small and located toward the anterior end of the fixed cheek. As the test is not preserved, there is only the cast in fine sandstone to show details of structure.

Free cheeks large and shaped much like those of *Menomonia*, except that they curve inward anteriorly so as to form a narrow, slightly elevated portion that fitted against the side of the projection in front of the glabella; as far as can be determined, the eye was at the interior anterior end of the free cheek; posteriorly the free cheek curves in against the fixed cheek in advance of the genal angle.

Remarks.—This species is represented in the material by several free cheeks and several cranidia. In spite of the crushed and distorted condition of the specimens because of the shale preservation, the cranidia show the same proportions and the extremely narrow projection serving as brim and border as is found in the holotype. It would appear from these specimens that *D. amata* Walcott never had more than this extremely narrow projection in front of the glabella, and that the wider brim and border found in *D. occidentalis* Lochman constitutes an additional specific character of that species.

There are only traces of glabellar furrows on these shale cranidia, but the weak devel-

opment appears to be due to the type of preservation.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Crepicephalus* zone, coll. B3.

HOLCACEPHALUS cf. H. ROBUSTUS Lochman
Plate 49, figure 10

Holcacephalus robustus LOCHMAN 1944, Geol. Soc. America, Sp. Paper 54, p. 76, pl. 8, figs. 50–54.

Original description.—Cranidium small with a prominent, broadly conical, tumid glabella; two pairs of short, glabellar furrows, posterior pair arcuate; dorsal furrow shallow, narrow; occipital furrow narrow, deep; occipital ring subtriangular, narrow, extended medially into a strong, slender, upcurved occipital spine. Posterolateral limbs of medium width and length, ending in a moderately long, heavy genal spine; intramarginal furrow broad and shallow. Fixed cheeks one-half width of glabella, flat; palpebral lobes small, crescentiform, situated somewhat anterior to transverse median line of glabella; narrow straight ocular ridge extending to front of glabella; frontal limb narrow, convex; transverse furrow narrow, shallow; frontal border very narrow, slightly convex; anterior margin nearly straight. Free cheek elongate with small eye at inner angle; ocular platform wide, slightly convex; narrow, well-defined marginal furrow; marginal border narrow, convex.

Facial suture cutting anterior margin well out at sides, curving out and back to and around palpebral lobes; thence curving diagonally outward and back to cut lateral margin above genal angle.

Pygidium not known.

Outer surface of test very finely granulated, with a few narrow parallel ridges along frontal border and marginal border of cephalon.

Remarks.—Only a single broken cranidium is so identified. The portions of the brim, border, tumid glabella, and posterior limbs which are preserved suggest strongly that this cranidium is the same species of *Holcacephalus* as occurs elsewhere in central Montana in the *Crepicephalus* zone; but the single specimen is not complete enough to warrant a positive specific identification.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Crepicephalus* zone, coll. B4.

MARYVILLIA ALBERTA Resser
Plate 48, figures 22, 23

Maryvillia alberta RESSER, 1942, Smithson. Misc. Coll., vol. 103, no. 5, p. 70, pl. 13, figs. 1–4.

Original description.—This species is founded on a single exfoliated cranidium, and a pygidium from a nearby locality is referred to it. The cranidium, typical in all respects, has a large glabella that tapers to a rounded frontal outline. Exfoliated specimens have a strongly developed keel. At the eyes the fixigenes are half the width of the glabella. The width of the simple, gently concave brim is a little less than the glabellar length. The eyes are slightly larger than usual. In both directions the convexity of the cranidium amounts to little.

The pygidium from a nearby locality, assigned to the species, has a prominent axis which tapers somewhat more than usual. The rear border occupies about one-third the pygidial length, which with the rather large eye, indicates the approach to *Coosia*.

Remarks.—This species is represented in the Little Rocky Mountain collections by five specimens (two cranidia and three pygidia) all of them quite poorly preserved as they occur on the weathered surface of an impure limestone nodule. Consequently, nothing can be added to the brief original description. The cranidia appear distinctive in the combination of the very narrow brim, broad, very shallow marginal furrow and the moderately wide, slightly convex border. It is suspected that the apparent low relief in this part of the cranidium may be largely attributed to weathering. The pygidium is quite distinctive in the regular and even downslope of the rather wide border. While weathering again makes it difficult to determine the exact end of the axis, it is thought to be 13 mm. or nearly two-thirds the length of the pygidium, while the border measures 7 mm. or one-third. This proportion is relatively high for a *Maryvillia* pygidium.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Crepicephalus* zone, coll. B3.

MARYVILLIA VIOLAENSIS Resser
Plate 48, figures 17–20

Maryvillia violaensis RESSER, 1942, Smithson. Misc. Coll., vol. 103, no. 5, p. 68, pl. 12, figs. 21–26.

Original description.—About a dozen cranidia and half as many pygidia have been located in the collections. Only two small cranidia are illustrated, as all the larger specimens are incomplete.

Two partially preserved cranidia show that the cranidium of the species attained a length of about 15 mm. and a width of about 25 mm. The glabella is poorly defined because the dorsal furrow is very shallow. Eyes, eye lines, and fixigenes are average in development. The brim on the other hand is excessively concave, and consequently the rim seems to be more distinct than usual. As a whole the cranidium is gently convex in a transverse direction and much more sharply convex longitudinally.

In the pygidium the axis is clearly outlined by a shallow dorsal furrow. Axial rings and the anterior pleural furrows are faintly indicated. The pleural lobes, nearly flat in their inner half, become convex in their outer portion. Longitudinally the pygidium slopes gently rearward.

Remarks.—To this species have been referred five small to medium-sized pygidia and very tentatively one small incomplete cranidium. The pygidia in limestone are quite well preserved. They are fairly broadly transverse in shape with a low convexity, and are characterized especially by a long tapered axis which occupies nearly three-fourths the length of the pygidium. The outer surface of the test is smooth except for short wavy ridges on the border, the inner surface is finely punctate.

It is quite difficult to compare these pygidia with the holotype of *M. violaensis* Resser because of the very poor preservation of the latter. Both this species and *M. loperi* Resser show the same proportion of axis to length as do these specimens, but *M. loperi*, preserved as casts of sand grains, is noticeably more convex in profile and the border is slightly concave. It is impossible to determine whether these features have been influenced by the preservation or not. Therefore, I have referred the Little Rocky Moutain specimens to *M. violaensis* which besides having approximately the same axis to length proportions appears to have a much less convex profile.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Crepicephalus* zone, coll. B4.

UNCASPIS aff. U. UNCA (Walcott)
Plate 48, figures 15, 16

Crepicephalus unca WALCOTT, 1916, Smithson. Misc. Coll., vol. 64, no. 3, p. 217, pl. 35, figs. 1d, 1d′, 1e.

Uncaspis unca (Walcott) KOBAYASHI, 1935, Imp. Univ. Tokyo, Jour. Fac. Sci., sec. 2, vol. 4, pt. 2, p. 279.

Uncaspis unca (Walcott) RAASCH and LOCHMAN, 1943, Jour. Paleontology, vol. 17, p. 223, pl. 34, figs. 1–5.

Uncaspis unca (Walcott) SHIMER and SHROCK, 1944, Index Fossils of N. America, p. 635, pl. 266, figs. 25–27.

Original description.—The pygidium of this species is not unlike that of *C. dis* from the House Range of Utah. It differs in having the two posterior spines of the pygidium near together and in their broader base where joining the flattened border. . . .

The largest pygidium has a length of 12 mm. exclusive of the spines.

Remarks.—One poorly preserved cranidium and two pygidia in shale, and one small cranidium (2 mm.) obtained from the limestone nodule carrying the specimens of *Maryvillia alberta* Resser are so identified. The shale specimens are so crushed and distorted that exact specific identification is impossible. The entire right pleural lobe of the best specimen has been bent down into a vertical position and there has been some lateral compression which has certainly brought the two pygidial spines closer together. It is impossible to estimate the amount of lengthening which may have occurred in the longitudinal axis. At present the proportions of length of axial lobe to posterior border appear to be most similar to those of *Uncaspis unca* (Walcott). It is interesting that its affinities appear to be with those of the Wisconsin species rather than the two previously described species from central Montana (Lochman and Duncan, 1944).

The small limestone cranidium appears to have a brim of medium width, and a border in nearly horizontal position. The position of the border may change with growth as is observed in the cranidia of *Uncaspis presbytera* Lochman, n. sp.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Crepicephalus* zone, coll. B3.

Cedaria Zone Fauna

ARAPAHOIA ASPINOSA Lochman
Plate 50, figures 12–18

Arapahoia aspinosa LOCHMAN, 1944, Geol. Soc. America, Sp. Paper 54, p. 116, pl. 10, figs. 8–13.

Original description.—Cranidium narrow, elongate with a low, conical glabella; no glabellar furrows; dorsal furrow shallow, narrow, only on inner surface; occipital furrow broad and very shallow; occipital ring narrow, arcuate, with a very small median node. Posterolateral limb short, broad with a well-defined intramarginal furrow. Fixed cheeks flat, very narrow; palpebral lobe crescentiform, situated a short distance anterior to transverse median line of glabella; frontal limb slightly wider than frontal border, both convex and continuing the downward slope of front of glabella, separated by a very faint, shallow transverse furrow; anterior margin bluntly pointed. Free cheeks narrow, elongate with a low ocular platform; no marginal furrow on exterior; narrow, convex marginal border ending in a short pointed anterior projection and a short slender

genal spine. Hypostome elongate, narrow, with an oval tumid central lobe, and a semicircular convex posterior lobe; lateral and posterior edges upturned to form a narrow rim.

Facial suture cutting anterior margin halfway out from center, curving outward and then passing straight back to and around palpebral lobes; thence curving outward and backward to cut posterior margin within genal angle.

Pygidium narrow, transverse; axial lobe wide, convex, extending nearly full length of pygidium, depressed posteriorly, divided into one well-defined anterior segment, and a broad terminal portion which shows traces of two more segments; pleural lobes nearly same width as axial, slightly convex, with two side segments marked faintly by pleural furrows; marginal border flat, narrow, with a short spine projecting from the anterior demisegment; a slight median indentation of the posterior edge.

Outer surface of test smooth on cranidium, roughened by low irregular ridges on pygidium; inner surface coarsely punctate.

Remarks.—This species is represented in several collections by a number of small and medium sized cranidia, some free cheeks, a few hypostomas and several pygidia showing well the single pair of small spines on the antero-lateral margin. The cranidia show the characteristic features of this species; 1) the absence of an occipital spine, 2) the very convex profile of the brim and border, 3) the brim and border approximately subequal with the border increasing in width on the median line due both to a slight backward bend of the marginal furrow and to a median point on the border, and 4) a facial suture diverging only very slightly forward.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, colls. B2, C1a, D1.

Arapahoia snowiensis Howell and Duncan
Plate 50, figures 5–11

Arapahoia snowiensis Howell and Duncan, 1939, Wagner Free Inst. Sci., Bull., vol. 14, no. 1, p. 6, pl. 1, fig. 10.

Arapahoia walcottae Resser, 1942, Smithson. Misc. Coll., vol. 103, no. 5, p. 46, pl. 7, figs. 12–14.

Arapahoia snowiensis Howell and Duncan, Lochman and Duncan, 1944, Geol. Soc. America, Sp. Paper 54, p. 120, pl. 15, figs. 1–9.

Original description.—Cranidium moderately convex, smooth. Glabella very large, tapered anteriorly, rounded in front, elevated above rest of the cranidium, marked by three faint glabellar depressions or furrows, which show only when the specimen is coated with ammonium chloride. Occipital furrow broad and shallow, anteriorly arcuate. Occipital ring prolonged into a short spine. Dorsal furrow better developed than in most described species of the genus. Brim narrow, slightly convex, equally divided into flattened rim and preglabellar areas by a faint transverse furrow. Fixed cheeks very narrow in front of eyes. Eye lobe of medium size, crescentiform. Posterolateral limb of fixed cheek short and wide, marked by a broad furrow near the posterior edge. Facial suture intramarginal nearly to the median line in front, rounds anterolateral angles of cranidium, extends backward and slightly inward to, and then around, eye lobe, then curves laterally and posteriorly to the posterior margin of the cephalon. Surface of cranidium smooth, except for minutely granulose areas surrounding the glabellar furrows. . . .

Supplementary description.—Lochman and Duncan, 1944. Free cheek elongate, moderately wide with medium-sized eye at inner angle; ocular platform slightly convex, three times width of narrow, flat marginal border; marginal furrow narrow, extremely shallow, only on inner surface; genal spine of medium length, slender.

Pygidium short, transverse; axial lobe of medium width, convex, extending four-fifths length of pygidium, divided into two well-defined anterior segments, a faint third segment, and a broad terminal portion; pleural lobes same width as axial, slightly convex, divided into three broad segments; marginal border narrow, flat, completely outlining posterior portion of pygidium; inner surface minutely punctate.

Remarks.—This species is represented by some small and medium sized cranidia, a few free cheeks and pygidia and several hypostoma. The latter have been figured as these are the first hypostoma referred to the species. The marginal furrow of the small free cheeks appears somewhat stronger than on the larger free cheeks of the plesiotypes from the Big Snowy Mountains, but this is considered a feature attributable to difference in size. The hypostoma are similar to those referred to *A. aspinosa* Lochman but differ from them in having a somewhat wider border so that the maculae appear more prominent.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, colls. B1, B2, A3, C1a, D1.

Arapahoia stantoni Resser
Plate 50, figures 1–4

Arapahoia stantoni Resser, 1942, Smithson. Misc. Coll., vol. 103, no. 5, p. 44, pl. 7, figs. 2–4.

Original description.—This species is similar to *A. spatulata* Miller in that the glabella is not separated by relief from the fixigenes. The very shallow dorsal furrow can be seen very clearly in cross light. The keel shows in about the same degree as

the glabella. Exclusive of the neck spine, the holotype cranidium, measured immediately in front of the eyes, is 13.7 mm. long and 8.8 mm. wide. The anterior margin of the brim is slightly angulated. Few specimens retain the slender neck spine. The associated pygidium has two pleural furrows clearly defined.

Remarks.—This species is poorly represented in the material. Only two large fragmentary cranidia and a large pygidium can be so identified. All of the specimens have the outer surface either deeply weathered or else largely peeled away so that the preservation is poor. They can be distinguished from the more abundant specimens of *A. snowiensis* Howell and Duncan in the fact that the cranidia of *A. stantoni* Resser are noticeably wider across the palpebral lobes in proportion to the length. An examination of the very poorly preserved type specimens of *A. reesidei* Resser 1942 indicates that it is a synonym of *A. stantoni* Resser.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, colls. B0 and B2.

Homagnostus cf. H. lochmanae Howell and Duncan
Plate 50, figure 19

Remarks.—A single pygidium and a poorly preserved small cephalon occur on a piece of shale from collection B1. It is probable that they belong to the same species. The pygidium looks very similar to those of *H. lochmanae* which occur in shale, but as it is completely flattened, a definite specific identification is questionable. The preservation of the cephalon is too poor to contribute any additional information.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, coll. B1.

Homagnostus sp. undet.

Remarks.—From collection B2 there was obtained a single badly broken cephalon which shows only that it does not have an anterior median furrow; and a single extremely small, but well preserved pygidium. Although it is apparently immature, the structure of the pygidium suggests that it belongs to *Homagnostus*. Both specimens are tentatively referred to that genus.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, coll. B2.

Kinsabia cf. K. varigata Lochman

Kinsabia varigata Lochman, 1940, Jour. Paleontology, vol. 14, p. 51, pl. 2, figs. 10, 11.
Kinsabia varigata Lochman, Lochman and Duncan, 1944, Geol. Soc. America Sp. Paper 54, p. 79, pl. 8, fig. 49.

Original description.—Individual plates depressed conical, with elevated acentric apices; a narrow short slope forward from the apex, and a long slope backward; margin flattened. Larger plates 3 mm. long by 2 mm. high.

Shell composed of a dark thick outer layer and a light thick central layer, each consisting of numerous lamellae; and a very thin innermost nacreous layer; each layer of uniform thickness over all parts of the shell.

Surface markings very distinctive, consisting of numerous strong wrinkles concentric with the apex, becoming finer near the apex; wrinkles covered with minute pustules, which become very prominent near the margin; natural gray of shell covered with patches of red, orange and purple.

Plates arranged in a graduated series increasing in size outward from a linear margin, which lies on the apical side of the plates.

Remarks.—A small number of separate plates are tentatively referred to this form. They occur in three collections from the *Cedaria* zone.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, Colls. B0, B2, C2.

Syspacheilus occidens Lochman, n. sp.
Plate 50, figures 25, 26

Cranidium quadrate, 3.5 mm. in length by 4 mm. across palpebral lobes; glabella broadly conical with broad rounded front, only moderately convex; no glabellar furrows; dorsal furrow broad, well-defined, fairly deep at sides; occipital furrow broad, well-defined; occipital ring of medium width, convex; brim narrow, slightly convex, downsloping; marginal furrow broad, shallow; border just slightly wider than brim, convex, downsloping; anterior margin evenly rounded. Fixed cheeks one-third width of glabella, convex, rising sharply from dorsal furrow to a horizontal position; palpebral lobe of medium size, crescentiform, situated on midline of glabella; palpebral furrow narrow, well-defined; no ocular ridge. Posterior limb short, narrow, two-thirds length of occipital ring, crossed by a broad, shallow marginal furrow. Free cheek not known. Facial suture cutting anterior margin on line with dorsal furrow, curving back to marginal furrow, then running

diagonally into and around palpebral lobes; thence running out and curving back to cut posterior margin within genal angle.

Thorax and pygidium not known.

Outer surface of test not known; inner surface finely punctate.

Remarks.—This species is described from one small but complete and well preserved cranidium, except for the absence of the outer surface of the test. The cranidium differs from the three previously described species both in the proportion of width of brim to border which is 1:2 and in the rather steep downward slope of both the brim and border. It appears to be closest to *S. dunoirensis* (Miller), the only other species which has been described from the Cordilleran region, but in that species the proportions between brim and border are nearly 1:3 and both have a less steep downward slope.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, coll. D1.

Cf. Syspacheilus occidens Lochman, n. sp.
Plate 50, figures 27–29

Pygidium broadly transverse; axis of medium width, moderately convex, slightly less than two-thirds length of pygidium, tapering only slightly to a broadly rounded end with a low triangular projection extending onto the border; divided by broad, well-defined furrows into four segments and a short terminal portion; dorsal furrow shallow, narrow, only along sides; pleural platform narrower than axis, triangular, flat neas dorsal furrow, then sloping down steeply, divided by broad shallow interpleural grooves into four wide segments; marginal furrow broad, shallow, running from anterior interpleural groove to side of posterior triangular projection of axis; border of medium width, flat, very slightly downsloping; posterior margin evenly curved, except for a straight line along median line.

Outer surface not known; inner surface finely punctate.

Remarks.—A large number of pygidia ranging in size from 4 mm. in length by 7 mm. in width to 14 mm. in length by 19 mm. in width occur in coll. D1. Because of the small size of the collection no cranidium can positively be associated with them. Nor can they be assigned to any described genus, though they certainly do represent the same genus and species as the small pygidium, C. L. 256, which was described as *Cedarina*? sp. undet. by Lochman and Duncan (1944, p. 94, pl. 14, fig. 9) from Dry Wolf Creek section. Resser assigned a small six-spined pygidium to *S. typicalis*, the genotype; but the association is no more convincing in Resser's material than in the Montana collections where the above described type of pygidium occurs.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, coll. D1.

Tricrepicephalus aff. T. simulans Resser
Plate 50, figure 23

Tricrepicephalus simulans Resser, 1938, Geol. Soc. America, Sp. Paper 15, p. 104, pl. 11, fig. 59.

Original description.—This species resembles both *T. nuperus* and *T. simplex*, being about halfway between the two species. *T. simulans* has some of the compactness of *T. nuperus* but is sparingly granulated on the preglabellar area. Also the three pits are simple.

Remarks.—Two fragmentary cranidia consisting of only the border, brim and very front of the glabella occur in coll. A3. Experience has shown that the width and position of the brim and border have specific significance in *Tricrepicephalus*. Thus it is possible to indicate the relationship of these fragmentary cranidia to the species described by Resser from the southern Appalachians. The Montana specimens have the brim and border of equal width, and their position and convexity is the same as that of the holotype of *T. simulans*.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, coll. A3.

Tricrepicephalus sp. undet.
Plate 50, figures 22, 24

Remarks.—One large well preserved free cheek and one small, fairly well preserved pygidium, 3 mm. wide × 2 mm. in length, can be referred to this genus but no specific determination can be made. The small pygidium has complete pygidial spines 3

mm. in length, ending in sharp tips. The spines appear to lie at about a 45° angle from the horizontal but it is difficult to determine this angle accurately since the axis, which is used as the datum plane, is broken off. Coarse granules can be seen on the pleural platforms and extending well down on the pygidial spines.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, colls. B2, D1.

MENOMONIA sp. undet.
Plate 51, figure 16

Remarks.—Three fragmentary small cranidia appear referable to *Menomonia* but the preservation does not warrant a specific determination. They all occur in limestone, but several are impressions, and none exceed 2 mm. in length. They are figured for future reference.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, coll. B2.

UNCASPIS Kobayashi 1935, emended Raasch and Lochman 1943

The recognition of the new species described below brings to our attention again the question of what to do with such ancestral forms. The structure of the fragmentary cranidia and of the many well preserved pygidia is clearly that of *Uncaspis* except that the pair of short pygidial spines is lacking. The species occurs in the highest *Cedaria* zone collection made in the Lodge Pole Creek section, but because of the covered condition of the intervening beds, this collection is at least 60 feet below the first shales from which *Crepicephalus* was obtained, so that its exact time relation to *Crepicephalus* cannot be determined. I believe that a more accurate picture of relationships is given by referring this species also to *Uncaspis* and emending the description of the pygidium to admit it, rather than erecting a new genus for this species alone.

Thus the description of the pygidium as given by Raasch and Lochman, 1943 would read—"Pygidium narrow, convex, roughly pentagonal, *usually* with a pair of rather closely spaced posterior spines. . . ."

UNCASPIS PRESBYTERA Lochman, n. sp.
Plate 51, figures 17–22

Cranidium narrowly elongate; glabella conical, tapered to a rounded front, con-

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EXPLANATION OF PLATE 50

FIGS. *1–4—Arapahoia stantoni* Resser. *1, 2*, dorsal and side views of a large peeled pygidium, ×2; *4*, dorsal view of large, broken associated cranidium, ×1, hypotypes, collection B0; *3*, dorsal view of smaller, partially peeled cranidium, ×1, hypotype, collection B2. (p. 341)

5–11—Arapahoia snowiensis Howell and Duncan. *5, 11*, dorsal and side views of large unpeeled cranidium, ×2; *9*, dorsal view of a smaller unpeeled cranidium, ×2, hypotypes, both collection C1a. *6*, a large hypostome, ×2, hypotype, collection D1. *7*, dorsal view of peeled cranidium, ×2; *8*, an associated free cheek, ×3; *10*, small associated pygidium, ×5, hypotypes, collection B2. (p. 341)

12–18—Arapahoia aspinosa Lochman. *12*, a large pygidium, ×2; *15*, a large associated free cheek, ×2, hypotypes, collection C1a. *18*, a partially peeled cranidium showing node on occipital ring, ×2; *16*, a small associated free cheek, ×2, hypotypes, collection D1. *13, 17*, dorsal and side views of a small peeled cranidium, ×2, hypotype, collection B2. *14*, a small peeled pygidium, ×4, hypotype, collection B0. (p. 340)

19—Homagnostus cf. *H. lochmanae* Howell and Duncan. Best preserved shale cast of the pygidium, ×3, hypotype, collection B1. (p. 342)

20, 21—Cedarina cordillerae (Howell and Duncan). *20*, dorsal view of largest, best preserved cranidium, ×3; *21*, a free cheek and very small cranidium, ×4, hypotypes, collection A2. (p. 347)

22—Tricrepicephalus sp. undet. A small pygidium with complete spines but broken axis, ×3, collection B2. (p. 343)

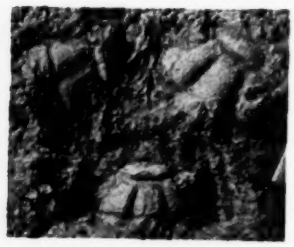
23—Tricrepicephalus aff. *T. simulans* Resser. Most complete cranidium, ×2, collection A3. (p. 343)

24—Tricrepicephalus sp. undet. A large, well preserved free cheek, ×1, collection D1. (p. 343)

25, 26—Syspacheilus occidens Lochman, n. sp. side and dorsal views of holotype cranidium, complete but peeled, ×3½, collection D1. (p. 342)

27–29—Syspacheilus cf. *S. occidens* Lochman. *27*, dorsal view of small peeled pygidium, ×3½; *28, 29*, side and dorsal views of larger peeled pygidium, ×2, collection D1. (p. 343)

Lochman, Montana Upper Cambrian fauna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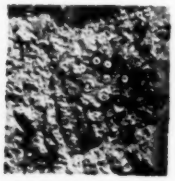
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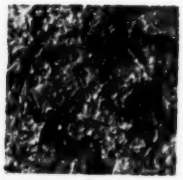
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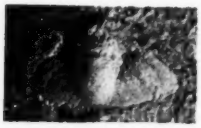
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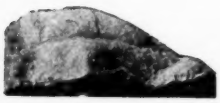
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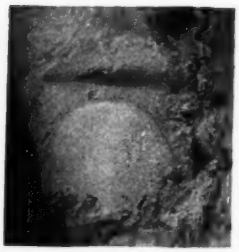
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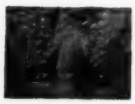
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22

Lochman, Montana Upper Cambrian fauna

vexity low, sloping down more steeply anteriorly; no glabellar furrows observed; dorsal furrow narrow, shallow; occipital ring of medium width, flat, with a flat median occipital spine; occipital furrow narrow, shallow; brim narrow, flat, downsloping in small forms, becoming horizontal in forms over 6 mm. in length; border narrow, flat, triangular, horizontal in small forms, becoming upturned to 60° in forms over 7 mm. in length; marginal furrow narrow, shallow; anterior margin bluntly pointed. Fixed cheeks non-existent; palpebral lobes narrow, arcuate, upsloping, medium-sized, situated slightly anterior to midline of glabella; no palpebral furrow observed; posterior limb of medium width, slightly less than occipital ring in length, crossed by a broad, shallow marginal furrow. Free cheek narrow, elongate, with medium-sized eye at inner angle; ocular platform narrow anteriorly, increasing slightly posteriorly, slightly convex and downsloping; marginal furrow narrow, shallow; border narrow, flat, slightly downsloping, with a long pointed anterior projection and a medium-length, slender genal spine. Facial suture cutting anterior margin at center, curving outward to marginal furrow, then running diagonally into and around palpebral lobes, thence curving out and back to cut posterior margin well within genal angle.

Thorax not known.

Pygidium slightly wider than long, convex; axis of medium width, moderately convex, approximately one-half length of pygidium, tapering to a well rounded posterior end which drops off steeply at sides, but from median base of axis a low tapered projection extends across the border almost to the posterior margin; axis divided by broad shallow furrows into two segments and a terminal portion; dorsal furrow narrow, only at sides; pleural platform slightly narrower than axis, triangular, steeply downsloping, divided into three broad segments by three broad shallow interpleural grooves; a narrow, shallow marginal furrow distinguishable posteriorly; border narrow anteriorly, increasing to medium width posteriorly, flat, continuing downslope of pleural platforms; posterior margin smoothly curved.

Outer surface of test smooth except for very low, interrupted imbricating ridges on border of cranidium and free cheek, and probably border of pygidium; inner surface finely punctate.

Remarks.—The appearance of this species of *Uncaspis* associated with *Arapahoia* and other genera diagnostic of the *Cedaria* zone, and stratigraphically below a *Crepicephalus* zone fauna in the Lodge Pole Creek section would suggest that in the northwestern part of North America, apparently in the direction from which *Uncaspis* migrated into the United States, the genus must be recognized

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EXPLANATION OF PLATE 51

FIGS. *1–3*—*Knechtelia ann* Lochman, n. gen., n. sp. *1*, group of three fragmentary cranidia, ×4; *3*, dorsal view of holotype, a nearly perfect cranidium, ×4, all collection A1. *2*, a large broken cranidium with an immature cranidium above on right and a cranidium of *Cedarina cordillerae* (H. and D.) on left, ×4, collection A2. (p. 348)

4, 5—*Kinsabia* cf. *K. varigata* Lochman. *4*, dorsal view of small piece showing broken apices of individual plates, ×5, collection C2. *5*, ventral view of another small piece, ×5, collection B0. (p. 342)

6–9—*Kormagnostus esterius* Lochman. *7*, *9*, dorsal views of large broken cephalon and smaller complete cephalon, ×3; *6*, *8*, dorsal views of two nearly complete pygidia, ×4, ×3, all hypotypes, collection A1. (p. 348)

10–15—*Armonia lata* (Howell and Duncan). *10*, *14*, dorsal and side views of a medium-sized cranidium, showing blurred surface, ×2; *15*, a smaller, flattened cranidium, ×2; *12*, a small, broken free cheek, ×3; *13*, a small associated pygidium, with blurred surface, ×5, all hypotypes, collection A2. *11*, dorsal view of a small, nearly complete cranidium, showing normal convexity and well preserved surface, ×3, hypotype, collection A1. (p. 346)

16—*Menomonia* sp. undet. Rubber cast from largest of impressions, ×6, collection B2. (p. 344)

17–22—*Uncaspis presbytera* Lochman, n. sp. *17*, *18*, side and dorsal views of largest associated broken cranidium, ×3, collection B0. 20, dorsal view of very small, nearly complete cranidium, ×3; *21*, a complete free cheek, ×2; *22*, dorsal view of holotype pygidium, with posterior portion of border broken away, showing doublure; *19*, impression of holotype pygidium showing absence of spines, and another broken pygidium, ×3, all collection B2. (p. 344)

as a member of the upper *Cedaria* zone assemblage as well as the *Crepicephalus* assemblage. Similarly in the Dry Wolf Creek section of the Little Belt Mountains species of *Uncaspis* appeared in the latest *Cedaria* assemblage (Lochman and Duncan, 1944, p. 132).

Uncaspis presbytera is very interesting structurally because of its greater age than other *Uncaspis* species. The pygidium is essentially that of *U. unca* (Walcott) in the proportions of the pleural platform to the axis and to the border, and in the convexity of the parts. The same striking tapering of the end of the axis posteriorly on to the border is present; but, while the border is slightly wider in the posterior median part, there is no trace of spines, only an evenly rounded margin. The pygidia and free cheeks are fairly well preserved, but, as usual, the cranidia are broken. The only two that are even moderately complete measure 1.5 and 2 mm. in length and are not quite mature. The rest of the cranidia, at least 10, are larger but consist only of the front part broken apparently on a line where the facial suture runs clear in to the dorsal furrow because of the non-existence of the fixed cheeks. An extremely interesting feature of the cranidia, and one which would support its ancestral position in the genus, is the change in position of brim and border during growth. Although the small number and fragmentary condition of the specimens limit study, its importance should be stressed as it is the first clearly demonstrable change with growth I have obtained. Thus—in cranidia 1.5 to 2 mm. in length, the brim is downsloping, the border is flat and horizontal; in cranidia 3 to 3.5 mm. the brim is still downsloping, the border is now slightly upturned; in 5 mm. cranidia the brim is nearly horizontal and the border is upturned at a 45° angle; and in a cranidium 12 mm. in length, the brim is quite flat and horizontal and the border is upturned at a 55°–60° angle.

Formation and locality.—Upper Cambrian, Pilgrim formation, *Cedaria* zone, coll. B2.

Lowest *Cedaria* Subzone Fauna
ARMONIA LATA (Howell and Duncan)
Plate 51, figures 10–15

Perioura lata HOWELL and DUNCAN, 1939, Wagner Free Inst. Sci., Bull., vol. 14, no. 1, p. 9, pl. 1, figs. 11–13.

Armonia lata (Howell and Duncan), LOCHMAN and DUNCAN, 1944, Geol. Soc. America, Sp. Paper 54, p. 122, pl. 15, figs. 29–37.

Original description.—Cranidium relatively flat. Glabella gently convex, more than three-fourths the length of the cranidium, tapered anteriorly, with straight side and rounded frontal outline. No glabellar furrows. Occipital furrow rather broad and shallow. Occipital ring gently convex, moderately wide. Dorsal furrow strong, entire. Brim narrow, subequally divided into flattened preglabellar area and gently convex rim by an almost straight transverse furrow. Fixed cheeks flattened, more than half the width of the glabella. Eye lobe crescentiform, approximately one-fourth the length of the glabella, situated opposite the middle of the glabella. Palpebral furrow broad, shallow. Postero-lateral limbs subtriangular in outline, marked by broad, rather deep marginal furrows. Facial suture intramarginal at least along antero-lateral edge of rim, rounds antero-lateral edge of cranidium, extends postero-medially to, then around, eye-lobe, thence nearly straight posterolaterally toward the genal angle, then turns abruptly to a postero-medial course to cut the posterior edge of the cephalon well in from the genal spine.

Free cheek large, inner surface ornamented with numerous anastomosing ridges radiating from the eye region to the border. Border at anterior portion of cheek much narrower than at postero-lateral angle. Genal spine large, projected postero-laterally at approximately 45° angle to long axis of body. Doublure of free cheek is approximately the same width as border, but does not vary in width.

Pygidium ovate in outline, flattened convex. Axis almost one-third width of, and nearly full length of, pygidium, moderately convex, with two or three distinct segments and a terminal portion; slightly tapered posteriorly. Dorsal furrow broad but deep laterally, interrupted posteriorly by a post-axial elevation extending to posterior margin of pygidium. Pleural lobes possess four distinct furrows extending to border; anterior furrows strong. Lateral border widened, slightly thickened and upturned. Border narrowed posteriorly and merged with post-axial elevation from axis.

Remarks.—A number of small cranidia, pygidia and a few free cheeks referable to this species occur in the lowest 10 feet exposed in a gully at the base of Sipary Ann Butte. The beds of limestone are only a few feet above a porphyry sill which has baked the surrounding shales and limestones. The preservation of the specimens is poor but interesting to study. It would appear that the ordinary cryptocrystalline replacement calcite of the fossils, under the influence of the heat, has experienced a gradual growth in the size of the calcite crystals. In the

specimens the replacement crystals are almost but not quite the same size as in the matrix, with the result that the specimens have a blurred appearance and all the details of the test and the outline appear to be fading away. In addition certain of the specimens show fracturing and distortion of the limestone.

The largest cranidia measure 13 mm. in length and 11 mm. across the palpebral lobes and occur in several lenses of limestone composed entirely of these cranidia and a few pygidia.

Formation and locality.—Upper Cambrian, Pilgrim formation, lowest *Cedaria* subzone, colls. A1, A2, A2′.

CEDARINA CORDILLERAE (Howell and Duncan)
Plate 50, figures 20, 21

Piedmontia cordillerae HOWELL and DUNCAN, 1939, Wagner Free Inst. Sci., Bull., vol. 14, no. 1, p. 9, pl. 1, fig. 4.

Cedarina cordillerae (Howell and Duncan), LOCHMAN and DUNCAN, 1944, Geol. Soc. America, Sp. Paper 54, p. 89, pl. 17, figs. 1–10.

Original description.—Cranidium gently convex. Glabella moderately convex, apparently without glabellar furrows. Occipital furrow strongly developed at sides, shallower medially. Occipital ring less elevated than posterior part of glabella, prolonged into large, posteriorly directed spine. Dorsal furrow deep, entire. Brim approximately one-fourth length of cranidium, subequally divided into convex preglabellar area and slightly upturned rim by a broad transverse furrow. Fixed cheeks approximately one-half width of glabella, slightly elevated above dorsal furrow, flattened or gently convex. Eye lobe very gently curved. Middle of eye situated anterior to a line drawn transversely through middle of glabella. Ocular ridge broad, distinct, curved postero-laterally from the antero-lateral portion of the dorsal furrow. Postero-lateral limb of free cheek rather long, moderately wide. Facial sutures diverge moderately in front of eyes, strongly back of eyes. Surface of cranidium smooth.

Pygidium, thorax and free cheeks unknown.

Corrections to description.—Lochman and Duncan, 1944.

The poorly preserved holotype cranidium shows a faint posterior pair of arcuate glabellar furrows, and well-preserved specimens in limestone show that three pairs of glabellar furrows were the normal number.

The frontal border is moderately convex (in limestone specimens) but is perfectly horizontal in position.

The transverse furrow has a slight posterior in-bend on the median line of the cranidium.

Ocular ridge narrow, moderately developed, crosses fixed cheek in a short arc straight to near front of glabella.

Posterolateral limb of fixed cheek of medium length and width, with a broad shallow intramarginal furrow which curves forward before reaching lateral margin.

Facial suture cutting anterior margin on line with dorsal furrow, curving out and back to transverse furrow, then running diagonally straight into and curving around palpebral lobes; thence running diagonally outward to beyond marginal furrow before curving abruptly down and in to cut posterior margin within genal angle.

Outer surface covered with fine granules; inner surface coarsely punctate.

Associated pygidium transverse; axial lobe of medium width, strongly convex, extending four-fifths length of pygidium, tapering markedly posteriorly, divided into four or five segments and a terminal portion; pleural lobes wider than axial, slightly convex, divided into four segments marked by very faint pleural furrows; marginal border of medium width, narrowing posteriorly, flat.

Remarks.—A few cranidia and free cheeks have been assigned to this species from the lower collections of Sipary Ann Butte. Like all the material they are poorly preserved and somewhat distorted, but they show fairly well the characteristic brim and border and the occipital spine.

Formation and locality.—Upper Cambrian, Pilgrim formation, lowest *Cedaria* subzone, colls. A1, A2.

Genus KNECHTELIA Lochman, n. gen.

Diagnosis of Cranidium.—1) palpebral lobes very small, situated just posterior to front of glabella.

2) glabella broadly conical; moderate regular convexity; three pairs of short faint glabellar furrows.

3) fixed cheeks nearly three-fourths width of glabella on midline.

4) fixed cheeks horizontal.

5) posterior limb somewhat wider than occipital ring.

6) brim, marginal furrow, prominent raised border.

Free cheek, thorax and pygidium not known.

The general convexity of the cranidium and the raised border suggest a relationship with the earlier Middle Cambrian genus, *Solenopleurella*. However, the latter differs markedly from *Knechtelia* in the size and position of the palpebral lobes, the presence of an ocular ridge and much stronger glabellar furrows. Among the described later Middle Cambrian forms there does not seem to be any similar appearing genus.

Genotype—*Knechtelia ann* Lochman, n. gen., n. sp.

KNECHTELIA ANN Lochman, n. sp.
Plate 51, figures 1–3

Cranidium subquadrate, 3 mm. across palpebral lobes by 2.85 mm. in length; glabella broadly conical, moderately convex; traces of three pairs of short glabellar furrows, first two pairs straight, third pair arcuate; dorsal furrow narrow, deep along sides but shallow across front of glabella; occipital furrow narrow, well-defined; occipital ring of medium length, slightly convex; brim narrow, flat, moderately downsloping; marginal furrow broad, deep; border of medium width, rim-like, rising vertically from marginal furrow, curving over at top and dropping down vertically in front; anterior margin curved. Fixed cheek nearly three-fourths width of glabella on midline, regularly convex, horizontal; palpebral lobes very small, arcuate, situated just back of front of glabella; almost on anterior one-fourth line through glabella; trace of a faint straight ocular ridge; posterior limb very long, occupying one-half length of glabella, slightly wider than occipital ring, crossed by a broad deep marginal furrow. Free cheek not known. Facial suture curving along vertical front of border, running diagonally in at sides to marginal furrow, then straight back to and around palpebral lobes; thence in a long curve outward and back to cut posterior margin within genal angle.

Thorax and pygidium not known.

Outer and inner surface of test unknown.

Remarks.—This new genus and species is represented by eight small cranidia in the two lower collections from Sipary Ann Butte. It is believed to be also present in some of the Middle Cambrian collections from the top of the Park formation of central Montana, but has never been described. The occurrence of the genus with two extremely early *Cedaria* zone species raises the question as to whether this collection should be placed in the extreme top of the Middle Cambrian or the base of the Upper Cambrian. The latter course is temporarily taken here until the highest Middle Cambrian faunule has been adequately described.

Formation and locality.—Upper Cambrian, Pilgrim formation, lowest *Cedaria* subzone, colls. A1, A2.

KORMAGNOSTUS ESTERIUS Lochman
Plate 51, figures 6–9

Kormagnostus esterius LOCHMAN, 1940, Jour. Paleontology, vol. 14, p. 24, pl. 2, figs. 32–35.

Kormagnostus esterius Lochman, LOCHMAN and DUNCAN, 1944, Geol. Soc. America, Sp. Paper 54, p. 77, pl. 5, figs. 15, 16; p. 141, pl. 12, figs. 13–18.

Original description.—Cephalon small, convex, 4 mm. long by 3.5 mm. wide, decreasing in width near occipital border; glabella narrow, conical, two-thirds length of cephalon, consisting of a large posterior lobe with a small central node, and a small nearly circular anterior lobe; posterior lobe strongly convex, but convexity decreasing markedly to the flat anterior lobe; two pairs of short glabellar furrows on posterior lobe; occipital lobes small, triangular, slightly convex; dorsal furrow wide, deeply impressed along sides of posterior lobe, joining with deep transverse furrow across front of lobe, but absent on outer surface around the anterior lobe. Cheeks same width as posterior lobe of glabella, strongly convex at sides, dropping abruptly down to deep, moderately wide marginal furrow; marginal border of medium width, convex.

Pygidium small, strongly convex, measuring 3.5 mm. in length by 4.5 mm. in width; axial lobe strongly convex, wide, extending to marginal furrow, with a small central node, below which lies a narrow, shallow V-shaped furrow; marked by traces of two pairs of short shallow furrows; dorsal furrows narrow, well-defined, running parallel to a place opposite the axial node, then diverging outward to give posterior portion of axial lobe a bulbous appearance; pleural lobes narrow, convex roughly subtriangular, tapering posteriorly; marginal furrow broad and shallow; marginal border of medium width, convex, with a short blunt spine at each side on line even with posterior edge of axial lobe.

Surface of test minutely granulated.

Remarks.—A number of good-sized cephala and pygidia of this species occur in

several collections from Sipary Ann Butte along with *Cedarina*, *Armonia* and the new genus, *Knechtelia*. Except for the usual blurring of all surface features due to the partial recrystallization of the calcite by the intrusion of a sill, the specimens are in every way typical of the species. Their appearance with the associated genera is interesting as this is a much earlier *Cedaria* zone assemblage than any in which the species has hitherto been recorded.

Formation and locality.—Upper Cambrian, Pilgrim formation, lowest *Cedaria* subzone, colls. A1, A2, A3.

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THE LOWER ORDOVICIAN *BELLEFONTIA* FAUNA IN CENTRAL MONTANA

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ABSTRACT—The occurrence in central Montana of a small fauna of three genera and species diagnostic of the *Bellefontia* zone is recorded. All are species previously described from Nevada and Alberta, Canada. Two of the genera have also been recently identified from a drill core in northeastern Wyoming. It would appear that shallow seas continued to occupy the shelf areas of Montana and Wyoming from the Upper Cambrian time until after the early Lower Ordovician (*Bellefontia*) time and that the absence of beds of the latter age over much of this region is to be attributed to post-early Ordovician erosion.

INTRODUCTION

IN THE Big Snowy Mountains near Half Moon Pass Deiss (1936) measured a 685 foot section of shales, limestones and limestone pebble conglomerates which he assigned to the Upper Cambrian and divided into two formations, the upper 32 feet referred tentatively to the Dry Creek shale and the remaining 653 feet[1] to the Pilgrim formation. In 1944 Lochman and Duncan (1944, p. 3) restricted the Dry Creek formation to dolomites and dolomitic siltstones. Consequently only a single lithic unit, the Pilgrim formation, is present in this section. Throughout the 685 feet of beds referred to the formation it is not possible to demonstrate any significant or recognizable change in the conditions of sedimentation until the top of the formation is reached. However, within the upper 127 feet two distinct faunas have been collected which are younger than any known fauna of the Trempealeauian. These faunas have been assigned (Lochman and Duncan, 1944, p. 4) to the earliest Lower Ordovician. The lowermost fauna, from the lower half of Deiss' $95\frac{7}{12}$ foot unit contains no described forms and is unnamed at present. The higher fauna, which is described in this paper, can be readily referred to the widespread *Bellefontia* zone.

The collection was obtained from the top 32 foot unit of Deiss' 1936 section, fossil locality 41/2—"the upper 5 to 8 feet containing large trilobite fragments" (Deiss, 1936). A few pieces, labeled 41/loose, were collected on the talus over this unit and the top of the underlying 95 7/12 foot unit. The specimens are all deposited at the U. S. National Museum, Washington, D. C.

The authors are deeply indebted to Dr. Charles Deiss for the opportunity to study and describe the material. The senior author wishes to thank Dr. Horace D. Thomas for permitting her to examine the specimens from the Wyoming core. The expense of the photography was defrayed by a grant-in-aid from the Geological Society of America.

DISCUSSION OF THE FAUNA

The fauna consists of some fragmentary graptolites and three trilobite species, *Bellefontia nonius* (Walcott), previously described from Alberta, Canada and listed by Stauffer (1941) from the Oneota dolomite of Minnesota, *Symphysurina spicata* Ulrich, described from the Eureka district, Nevada and also listed by Stauffer from the Oneota dolomite, and *Xenostegium* cf. *X. kirki* Walcott described from Alberta, Canada. The specimens of this small Montana collection show the same type of poor preservation which characterizes the described specimens from other Cordilleran localities. All of the Montana specimens are weathered since only the fossils occurring on the shale partings of the thin-bedded dense limestone can be obtained. It has not been found possible

[1] The lower 616 feet of Deiss' 1936 section plus the upper 47 feet of the top shale unit of the Park formation, so drawn to include all of Deiss' fossil locality 41/3 which the authors and Deiss in 1938 found to belong to the *Cedaria* zone.

to break any fresh specimens from these dense limestones. Moreover, the larger cranidia and pygidia have been crushed and flattened, and it is difficult to reconstruct their true proportions. The small size of the collection appears to be largely responsible for the small size of the faunal assemblage at this locality. Brachiopods, a number of gastropod genera and several more trilobite genera are known to accompany these forms at other localities.

Recently the senior author identified a *Bellefontia* pygidium and a *Symphysurina* cranidium (see figs. 7, 13) at 4,238 feet in the core of the Union Oil Company of California and Ohio Oil Company No. 1 Government well, Bull Creek anticline, Sec. 3, T. 57 N., R. 62 W., Crook County, Wyoming. The specimens occur in a calcareous sandstone near the top of the Deadwood formation as recognized on lithologic evidence. The senior author has also collected specimens of the earlier Ordovician unnamed fauna in the Deadwood section along Spearfish Canyon in the Black Hills. The occurrence of the *Bellefontia* fauna in a nearby region is most significant from a paleogeographic standpoint.

The presence of early Lower Ordovician faunas in the top of the Pilgrim formation in central Montana and the top of the Deadwood formation in the Black Hills and northeastern Wyoming suggests that the early Lower Ordovician seaway of this northern Cordilleran area was essentially as widespread as that of the preceding Upper Cambrian, and in this shallow shelf area the same conditions of sedimentation prevailed throughout the Upper Cambrian and the early Lower Ordovician. The scattered distribution of the *Bellefontia* fauna in this area now seems best explained as caused by subsequent removal by erosion in Ordovician and later times, although in all sections the contact of these beds with the overlying Bighorn or Jefferson formations appears conformable.

CORRELATION OF THE FAUNA

The three trilobite genera of this fauna are rather widely distributed throughout the United States and Canada and have been considered diagnostic of a faunal zone somewhere near but not actually at the base of the Lower Ordovician. The top beds of the Pilgrim formation in the Half Moon Pass section and the top beds of the Deadwood section in Crook County, Wyoming which carry these genera can be correlated with a number of formations. In the Canadian Rockies a similar trilobite assemblage was early reported from the Mons and the Chushina formations of Alberta and British Columbia (Walcott, 1925). Farther south a larger and more complete representation of the *Bellefontia* zone has recently been listed by Williams (1948) from the lower part of the Garden City formation (Ross, personal communication) in the Logan Quadrangle, Utah. Walcott had earlier (1925) recorded a species of *Xenostegium* from near Malad, Idaho. In the Goodwin formation of the Eureka district, Nevada, and at Queen Spring Hill just south of Shellbourne Pass, Nevada, two more occurrences of the fauna have been reported by Walcott (1925). In the Mississippi Valley province the *Bellefontia* zone is known from the Oneota dolomite of Minnesota (Stauffer and Thiel, 1941); the Gasconade formation of Missouri where only *Hystricurus* has been recorded with many of the characteristic gastropod genera (Bridge, 1930); and the McMichel member of the McKenzie Hill formation of Oklahoma where *Hystricurus* occurs with *Symphysurina* (Frederickson, 1941). In the Appalachian province the lower Stonehenge limestone carries several brachiopod and gastropod genera associated with *Bellefontia collieana* (Raymond) (Butts and Moore, 1936).

BELLEFONTIA NONIUS (Walcott)

Plate 52, figures 1–6

Niobe? nonius WALCOTT, 1923, Smithson. Misc. Coll., vol. 67, no. 8, p. 473.

Bellefontia nonius (Walcott) WALCOTT, 1925, Smithson. Misc. Coll., vol. 75, no. 3, p. 72, pl. 23, figs. 7–11.

Original description.—This species averages larger in size than [*B.*] *collieana*. In the cranidium the greatest difference between the two species lies in the slightly different front. [*B.*] *nonius* has a flatter rim, but the glabella is marked off in much the same way except that it is more expanded anteriorly. The head is less convex in longitudinal cross-section and the palpebral lobes are also slightly smaller.

The free cheek assigned to [*B.*] *nonius* has pre-

served the extension of the doublure for a considerable distance beyond the cheek. The suture is intramarginal.

The pygidia associated with [*B.*] *nonius* are not unlike those of [*B.*] *collieana*, except that the axial and pleural ribs are less well developed.

Remarks.—This species comprises the greater number of specimens in the material, and all parts of the disarticulated carapace are known. However, the preservation of all specimens is poor as on all of them the outer surface has been weathered and both cranidia and pygidia have been fractured by compression. The cranidia of the Montana specimens are hard to judge for proportions, but measurements taken on a number of cranidia give approximately the same proportions for both the Canadian and the Montana cranidia. The associated free cheeks and pygidia appear to be very similar. The pygidia are especially distinctive in having the peculiar rounded expansion at the end of the axis. The Montana pygidia show the same weak appearance of pleural and axial segments, but as both Canadian and Montana pygidia are equally deeply weathered, it cannot be stated definitely whether this is a true specific feature.

Formation and locality.—Lower Ordovician, uppermost beds of the Pilgrim formation, *Bellefontia* zone, colls. 41/2, 41/loose.

Types.—Hypotypes, cranidia, T.1594; hypotypes, pygidia, T.1595, T.1591; hypotypes, free cheeks.

SYMPHYSURINA SPICATA Ulrich
Plate 52, figures 8–12

Ampyx? WALCOTT, 1884, Pal. Eureka District, Monogr. U. S. Geol. Survey, vol. 8, pl. 12, fig. 19

Symphysurina spicata Ulrich, WALCOTT, 1925, Smithson. Misc. Coll., vol. 75, no. 3, p. 113, pl. 21, figs. 12–18.

Symphysurina eugenia WALCOTT, 1925, Smithson. Misc. Coll., vol. 75, no. 3, p. 113, pl. 21, figs. 25–29, 31, 32.

Original description.—Trilobite small, the typical variety probably not exceeding 25 mm. in length. Cranidium relatively a little longer than the average for the genus, moderately convex, arching (in longitudinal direction) uniformly from the posterior edge to within a fifth of the length from the anterior edge where the profile straightens and finally becomes concave as it passes through the hollow, frontal border; sutural edges diverging very slightly and almost straight in the first halves of their courses forward from the eyes, then turning inward around the anterolateral angles which, therefore, are broadly rounded; front part of outline slightly angulated medially, the outer part of the flat border with a delicately tri-striated band forming a barely raised rim; dorsal furrows moderately impressed between the posterior edge and the eyes, obsolete forward; neck furrow unrecognizable exteriorly, but a very narrow neck ring is suggested on interior casts; palpebral lobes of medium size, drooping but slightly, situated entirely behind the midlength; posterior limbs short and not much attenuated laterally.

Free cheeks, subtriangular, depressed convex, without elevated border; but having a long genal spine which is directed more outward than backward. The anterior edge of the cheek is bent near its middle and nearly straight on either side, the outer of the straight halves extending to the tip of

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EXPLANATION OF PLATE 52

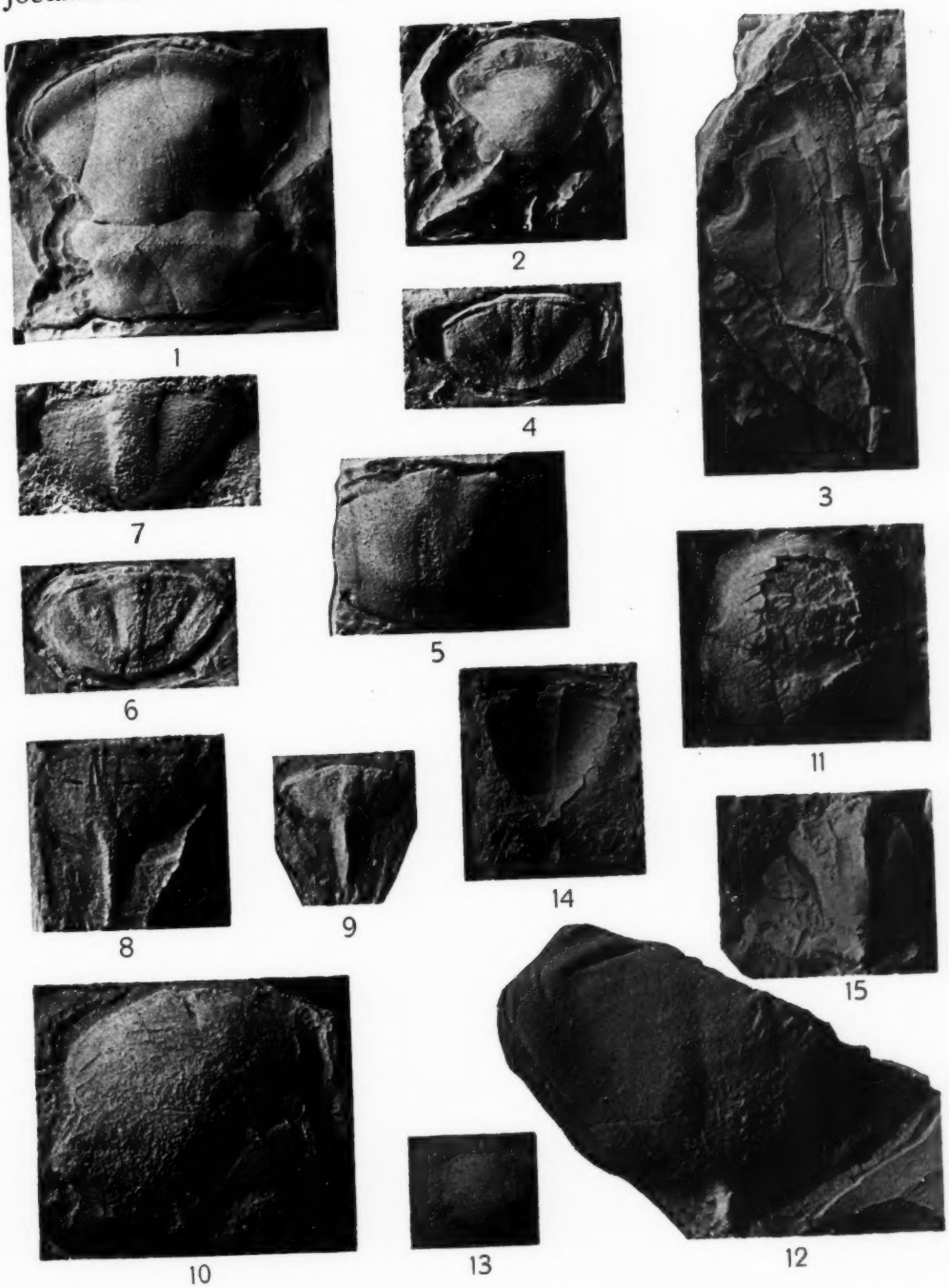
FIGS. *1–6*—*Bellefontia nonius* (Walcott). *1*, dorsal view of largest cranidium, ×1, T.1594; *2*, dorsal view of smaller incomplete cranidium, ×1; *5*, dorsal view of largest but badly weathered pygidium, ×1, T.1595; *4*, dorsal view of smaller pygidium, ×1, all coll. 41/2. *3*, a large free cheek, ×1; *6*, dorsal view of small pygidium, ×2, T.1591, both coll. 41/loose, Half Moon Pass, Montana. (p. 351)

7—*Bellefontia* sp. Sandstone mold of pygidium, ×2, at 4238 ft. in core of Union Oil No. 1 Bull Creek, Crook Co., Wyoming. (p. 351)

8–12—*Symphysurina spicata* Ulrich. *8*, dorsal view of weathered medium-size pygidium, ×2; *9*, a small weathered pygidium, ×2, T.1599; *10*, dorsal view of largest, best preserved cranidium, ×2, T.1598; *11*, smaller badly weathered cranidium, ×2; *12*, large broken pygidium with well preserved inner surface of test, ×2, T.1600, all coll. 41/2, Half Moon Pass, Montana. (p. 352)

13—*Symphysurina* sp. Sandstone mold of a small fragmentary cranidium, ×2, at 4238 ft. in core of Union Oil No. 1 Bull Creek, Crook Co., Wyoming. (p. 351)

14–15—*Xenostegium* cf. *X. kirki* Walcott. *14*, impression of interior of pygidium, showing spine, ×1, T.1601; *15*, dorsal view of a badly crushed pygidium, ×1, both coll. 41/2, Half Moon Pass, Montana. (p. 353)



Lochman and Duncan, *Bellefontia* fauna in Montana

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the genal spine, the other to the facial suture. Here the edge passes to the doublure, the direction at the same time having to bend a little forward so as to conform with the obtusely angular frontal edge of the cranidium.

Thoracic segments narrow, nearly smooth or at least not deeply furrowed, the axial and pleural parts approximately equal in width, the extremities tapering almost to a point without recurving.

Pygidium, exclusive of spine, broadly triangular, fully twice as wide as long, unsegmented exteriorly; axis convex though obscurely defined exteriorly, fairly well defined and with traces of three or four segments in casts of the interior, extending to the posterior edge beyond which it is prolonged as a slender and relatively long spine; pleural lobes gently convex, divided obliquely into subequal parts by an obscure linear depression or groove, otherwise smooth.

Remarks.—Two cranidia and eight pygidia represent this species. All are weathered on the surface, but one cranidium and several of the pygidia show the outline and specific features fairly well. Examination of the types of this species and *S. eugenia* Walcott at the U. S. National Museum revealed that they all belong to the same species, although the material of *S. eugenia* has the pygidia quite poorly preserved. The body of the pygidia is the same in structure in both species, but no pygidia of the latter species have the axial posterior spine preserved, therefore, Walcott could not possibly have determined that the spine was shorter than that in *S. spicata*. The cranidia are exactly alike, in spite of Walcott's attempt to find a slight distinction; and the absence of a genal spine on the free cheek referred to *S. eugenia* is caused by the specimen's poor preservation. We have chosen to recognize *S. spicata* Ulrich rather than *S. eugenia* Walcott in placing the two species in synonymy because the former is represented by much better preserved type material.

Formation and locality.—Lower Ordovician, uppermost beds of the Pilgrim formation, *Bellefontia* zone, coll. 41/2.

Types.—Hypotypes, cranidia, T.1598; hypotypes, pygidia, T.1599, T.1600.

XENOSTEGIUM cf. X. KIRKI Walcott

Plate 52, figures, 14, 15

Xenostegium kirki WALCOTT, 1925, Smithson. Misc. Coll., vol. 75, no. 3, p. 127, pl. 24, figs. 18–21.

Original description.—This species is closely allied to *Xenostegium goniocercum*. The glabella is expanded to a slightly greater degree and its better preservation permits a more complete illustration of the characters of the genus. The pygidium is also quite similar.

Remarks.—Only two poorly preserved pygidia occur in the collection which can even be tentatively referred to this species. They add nothing to a knowledge of the species, and are placed here only because they do show the rather small short straight spine coming off the posterior border on the median line, a feature which seems to be the only distinquishing feature in the type pygidia. Much of Walcott's material of the species of *Xenostegium* is also poorly preserved, and it appears that considerable revision of species is needed when adequate well-preserved material is available.

Formation and locality.—Lower Ordovician, uppermost beds of the Pilgrim formation, *Bellefontia* zone, coll. 41/2.

Figured specimens.—Impression of pygidium, T.1601.

MANUSCRIPT RECEIVED JULY 6, 1949

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A CLASSIFICATION OF THE JURASSIC AMMONITES

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PURPOSE OF THIS PAPER

THE subject of this paper has been pondered by the author for a considerable time in the course of systematic work on particular groups. Two facts have stood out. First, that the Ammonoidea offer perfect material for experimenting with, improving, and moulding a classification that shall reflect current ideas of relationships in time and space. Second, that all the textbooks are at least a quarter of a century out of date and to judge by the literature the present state of classification of the order is chaotic.

A long-term program to reconcile these two facts has been given urgency by the project for an international Treatise on Invertebrate Paleontology initiated by the Paleontological Society in America. The present paper propounds a scheme of classification in the hope of attracting constructive criticism, so that by the time the Treatise goes to press the Mesozoic Ammonoidea shall have the best possible systematic treatment compatible with present-day knowledge. Any corrections and criticisms, whether privately communicated or printed, will be welcomed and considered.*

TAXONOMIC SCALE

Genera and species.—It has repeatedly been pointed out by Bather and others that the primary object of a classification is to be useful. The systematic categories most frequently, and in ordinary interchange of ideas between paleontologists invariably, used are the genus and species. Neither in speech nor in writing do we say that a bed is dated by the finding of a "Mollusca, Cephalopoda, Ammonoidea, Stephanoceratacea, Macrocephalitidae, *Macrocephalites* (*Kamptokephalites*) *herveyi*." We say that we have found a *Macrocephalites herveyi*. The other systematic categories are an academic matter, and they must be scaled up or down in such a way that they shall be subservient to the usable, conventional genus. They never appear except in monographs and textbooks, and it is immaterial in practice what value is placed on any particular term in the hierarchy and how many terms the hierarchy shall contain.

Theoretically, at least, the number of species named reflects the number of forms, and so is more or less an objective matter. The genus, however, represents a subjective grouping of species to indicate supposed relationships and is wholly dependent on the judgment of the paleontologist. Here is where the systematist has the opportunity to pitch his classification on such a scale that it shall be acceptable and useful to his colleagues. If he insists on too many genera his judgment is at fault and his classification will be unusable and remain unused. He need not compromise with his conscience and suppress differences which he knows exist, for these can be expressed in the creation of subgenera. Anyone making a collection of *Kosmoceras* from an Oxford Clay pit will want to classify them in Buckman's "genera" *Kosmoceras, Bikosmokeras, Lobokosmokeras, Spinikosmokeras, Kuklokosmokeras*, etc., but he will never feel called upon to abandon the generic name *Kosmoceras* in favor of these in practical parlance; in any case, the differences between them are often so subtle, and their nomenclatural stability so dubious and unpredictable, that full justice is done them when they are enshrined as subgenera in the monographs and forgotten.

Moreover, the creation of too many genera defeats one of the principal objects of binomial nomenclature: namely, to indicate relationships between species by grouping like species under the same name. The logical conclusion of such a procedure as Buckman's in splitting up the genus *Dac-*

* For preliminary reading of the typescript and for suggestions, I am grateful to Mr. C. W. Wright, Mr. D. T. Donovan, Dr. B. Kummel, and Mr. Francis Hemming.

tylioceras into some thirty new genera is to have every species in a different genus: at which point all genera might as well be abandoned and a return made to *Ammonites*.

Families and subfamilies.—Families and subfamilies again are purely subjective categories, representing convenient and supposedly significant groupings of genera. The numbers of each required will be largely dependent on the number of genera recognized; but to some extent the quantity is determined by convention and the number of names already existing and usually recognized. In the 1920's new families were created at a great pace, but in the 1930's and 1940's there has been a tendency to down-grade many of them to subfamilies. It is unavoidable that the subfamilies of some authors should overlap with or be equivalent to the genera of others.

HIGHER TAXONOMIC CATEGORIES, AND THE BASES OF CLASSIFICATION

The higher taxonomic categories, however, begin to be controlled from above, by the necessity that they shall reflect the major natural subdivisions of the order Ammonoidea and the main relationships indicated by current evolutionary theory.

Having started at the bottom of the hierarchy, with the genus and species, and worked upwards, we now turn to the top, to the Order Ammonoidea, and work downwards, leaving the families and subfamilies in the middle to take care of themselves.

In subdividing the Ammonoidea, and confining ourselves for simplicity to the Jurassic and Cretaceous members, the first objective is to reflect in our classification the three great subdivisions recognized by E. Suess in 1865, when he split off from the rest of the ammonites the two genera *Phylloceras* and *Lytoceras*. The importance of these two conservative stocks and their special relationships to the rest of the order have been brought out with increasing clarity as research has progressed (though the details of those special relationships are still far from certainly understood). These three great main trunks of the Ammonoidea are here expressed as the suborders Phylloceratina, Lytoceratina, Ammonitina, using the form of suborder termination first recommended for the international Treatise on Invertebrate Paleontology.

Within the suborders Phylloceratina and Lytoceratina little further subdivision is necessary for the Jurassic forms until the rank of family. But within the suborder Ammonitina there are major subdivisions of fundamental significance in the light of evolutionary theory, and for these the category of superfamilies is now used.

Since 1920, the basis of classification at the superfamily level has been revolutionized by Salfeld's theory of Iterative Evolution. According to this theory the Ammonitina were again and again replenished, sometimes perhaps wholly replaced, by evolutionary radiations from the conservative suborders Phylloceratina and Lytoceratina, mainly from the latter. How often major replenishments have taken place is highly controversial, but some seem to be fairly satisfactorily established. The first of these radiations, from some offshoot probably of the Triassic Monophyllitidae, gave rise to the Psiloceratidae of the Hettangian and through them presumably to the other Arietitaceae of the Sinemurian and early Pliensbachian. In the Sinemurian there was a wave of evolutionary radiations from Lytoceratina, which gave rise to the Eoderoceratacеae (olim Deroceratida). These continued to flourish until the end of the Pliensbachian; for it has been shown that the Liparoceratidae of the uppermost Lower Lias probably gave rise to the Amaltheidae of the Middle Lias. During the lower Pliensbachian another radiation from the Lytoceratina produced *Prodactylioceras* and thence at least part of the family Dactylioceratidae, though Dr. Spath thinks that another part of the family was derived more indirectly from Eoderoceratidae.

In the Domerian another great superfamily arose, the Harpoceratacеae, which flourished through the Toarcian and Aalenian, giving rise to the important families Hammatoceratidae, Sonninidae and Graphoceratidae of the Aalenian and Bajocian and probably lingering on for a final burst as the Clydoniceratidae of the Bathonian. The Harpoceratacеae probably rose from the Polymorphitidae. (See footnote below.)

During the Bajocian three new superfamilies arose, the Stephanoceratacеae,

Perisphinctaceae, and Oppeliaceae. The first died out in the Lower Kimeridgian with *Amoeboceras*, the last of the Cardioceratidae.[1] The second and third lasted until the Cretaceous and between them account for the whole vast "trachyostracous" ammonite population of the second half of the Jurassic period; for after the Bajocian there were no more major innovations. Before the last Stephanoceratids died out, the Oppeliaceàe like the "leiostraca" left British seas, and although they continued to flourish in the Tethys and elsewhere until the Cretaceous, Britain was left from the end of Lower Kimeridgian times onwards in sole possession of the Perisphinctaceae. This fact is certainly to be correlated with the progressive differentiation and isolation of marine faunas in the Upper Jurassic. The next new invaders were the Russian Craspeditidae that came into Lincolnshire in the Neocomian.

The Oppeliaceae are regarded with Buckman as including the Haploceratidae, because almost certainly Haploceratidae gave rise to Oppelidae, not only once but perhaps several times. The two stocks are too intimately linked at various levels to separate as two superfamilies; though a separate origin for some Bajocian Oppelidae from the Harpoceratacean Sonninidae cannot be ruled out. The origin of the Haploceratidae in turn is problematic. As shown in the diagram, they may have arisen direct from Phylloceratina or from Harpoceratacae via the Middle Toarcian *Praehaploceras*, as supposed by Monestier.

On the other hand, the perisphinctids, usually included in the Stephanocerataceae, are here regarded (with Wedekind) as a separatesuperfamily Perisphinctaceae, partly because of their cryptic and probably independent origin and partly because of their distinctiveness, their vast numbers, and their long range, which far transcends that of all the Stephanocerataceae. The first European Perisphinctaceae appear (as true Neumayrian cryptogenes) at the base of the Upper Bajocian (basal Subfurcatum Zone), but in Sinai true Perisphinctids occur in the Middle Bajocian Humphriesianum Zone, where they are already quite distinct from any Stephanocerataceae. Perisphinctaceae therefore may have had a common and simultaneous origin with Stephanocerataceae in the Lower Bajocian *Erycites;* which would give both superfamilies a descent from Hammatoceratidae (Harpocerataceae).

A logical classification of the Perisphinctaceae is perhaps an impossibility. To bring any order into so baffling a mass of forms remains the hardest task in ammonite systematics. In general, two kinds of evolutionary changes can be distinguished. First there are specialized dead-end radiations from the main stock, which may be compared to buds given off from a twig or branches from a tree. Secondly there are more general and more subtle changes of the main stock itself, generally expressed as changes of ribbing habit, which produce groups that may be compared to the drums composing a column (though the joints between the drums are usually oblique). Criteria of the second kind are the only reliable ones for dating, but it is not always easy to disentangle the two kinds, and still more difficult to decide how they should be expressed in a classification.

The dead-end offshoots take the form of a number of trends in well-known directions, which may be repeated an indefinite number of times. Four trends are the most important: (1) towards a smooth, more or less involute, discoidal shape, imperfectly copying the oxycones of other superfamilies. Examples: certain *Procerites* in the Middle Bathonian, *Proplanulites* in the Callovian, *Ringsteadia* in the Upper Oxfordian, *Sublithacoceras* in the early Upper Kimeridgian, *Craspedites* in the Upper Volgian. (2) towards depressed, sphaeroidal cadicones. Examples: *Gravesia* in the Middle Kimeridgian, *Polyptychites* in the Neocomian: (3) a smooth band on the venter. Examples: *Parkinsonia* in the Upper Bajocian and Lower Bathonian, *Proplanulites* in the Callovian, *Idoceras* and *Aulacostephanus* in

[1] The resemblance of the Stephanocerataceae end-forms *Prionodoceras* and *Amoebites* (subgenera of *Amoeboceras*) to the Eoderocerataceae end-forms *Amaltheus* and *Pleuroceras* is truly remarkable. It suggests to me a common origin for Amaltheidae and Cardioceratidae in Eoderocerataceae; and since Stephanocerataceae were derived from Harpocerataceae, this implies that Harpocerataceae were derived from Eoderocerataceae, as held by Haug.

the Kimeridgian, *Berriasella* in the Upper Tithonian: (4) shortening of the primary ribs and elongation of the secondaries. Examples: *Wagnericeras* in the Upper Bathonian, *Indosphinctes* in the Callovian, *Aulacostephanus* in the Kimeridgian. At certain times and certain places, for example during the Koenigi and again the *Cymodoce-Pseudomutabilis* zones in England, some of these offshoots dominated the scene and may be mistaken for the main stem; but other areas show that the more conservative perisphinctid main stock persisted all the time and later migrated to repopulate the outlying northern areas after extinction of the specialized offshoots.

The progressive changes that occurred independently of these offshoots are more subtle and difficult to define. If plaster casts of certain Leptosphinctinae from the Upper Inferior Oolite and *Choffatia* from the Cornbrash were inserted into a collection of plaster casts of Upper Oxfordian perisphinctids from the Corallian Beds it might be impossible to sort them out; so little did the "typical" perisphinctid characters change throughout that long span of time. But in the Kimeridgian definite pecularities of rib habit and furcation set in, which make approximate dating less hazardous. Such changes are the basis of the families Ataxioceratidae, Virgatosphinctidae and Pseudovirgatitidae, but in the present classification they are down-graded to two subfamilies (the distinction between the last two does not seem to be objective). It is a fault for which no remedy is apparent, that these cross-sections of the main stock, or "column-drum" divisions, should have to be equated with the "dead-end" offshoots as equal taxonomic units.

At the end of the Jurassic, when the progressive geographical isolation of the marine faunas reached its climax, the Perisphinctaceae split up in different regions into several parallel branches, of which at least three carried over into the Cretaceous.

NOMENCLATURAL PRINCIPLES

Genera and Subgenera.—The International Rules of Zoological Nomenclature are explicit on the use of these categories. The type species of each has been checked in the light of the Rules. Correction of the type of a genus may radically affect the concept of the family based upon the genus (e.g. in Ammonitidae and Arietitidae; see Note 8 below.) Some points that in the past have caused uncertainty were cleared up by revision of the Code of Rules at the 1948 meeting of the International Zoological Congress, and decisions affecting them will be incorporated in the revised Code now being drafted.

The most important of these points affecting ammonites is the decision that when a genus is based on a named existing species and a misidentified specimen or specimens, the nominal species is the type. Again (a variant of the foregoing case), when a genus is based on a numbered specimen in a museum, identified even only tentatively by its author with an existing named species, that named species is the type of the genus: the specimen referred to, being unnamed and unpublished, has no status in nomenclature and the first named species mentioned in connection with the new genus is automatically the genotype by monotypy. The object of this decision of the Commission is to ensure that the names of genera shall be based upon objective nomenclatorial facts and shall not be subject to change in the light of subjective opinions of later revisers. The decision affects a number of Liassic genera.

An application has also been made to declare null and void the doubtful and disused early generic names *Orbulites* and *Planulites* Lamarck 1801, *Ellipsolithes* Montfort 1808, *Globites* and *Planites* de Haan 1825. Irresponsible selection of type species for these forgotten nominal genera is a potential menace to the whole of ammonite classification.

Buckman's list of 1898 (Quart. Journ. Geol. Soc. London, vol. 54, p. 459) headed "In most cases the name which stands first may be considered as the type-species" cannot be accepted as giving valid type-designations for genera of which the types had not already been fixed, for Article 30, rule (g) states that "the meaning of the expression "select the type" is to be rigidly construed." Buckman's "names which stand first" therefore become valid only from the date at which they may have been specifi-

cally cited as type species by a subsequent author.

Families and subfamilies.—These have been treated as nearly as possible in the same way as genera and in accordance with Articles 4 and 5 of the Rules and with Opinions 133 and 141.

The rule of priority applies to families only in a special sense; for Article 5 states that if the name of the type genus of a family has to be changed, the name of the family must change also. In other words, the priority attaches to the genus and not to the name. (For examples see Notes 11 and 26 below.)

The Rules do not clearly state in what form a term to denote a supergeneric group must be published in order to qualify as a family name. In this paper, in accordance with the general practice of workers on the Ammonoidea, any term published in Latin or Latinized form for a group of genera is accepted as a family name, irrespective of the termination with which it was first published. By Article 4 the root-stem of the name of the type genus automatically takes the termination *-idae* when the name is used as a family, or *-inae* when used as a subfamily. (For examples see Notes 12, 32, below.)

A family name need not be based upon the oldest genus in the family; family names can be based upon any included genus at the discretion of the proposer (Opinions 133 and 141).

Family names not formed on a type genus are invalid. (For examples see Notes 6, 31, below.)

The scope of a family, provided that it contains the type genus, is (like the scope of a genus) a subjective matter depending on the judgment of individual systematists. The expression "Emended X" is unnecessary, because most families and genera have been emended out of recognition by successive authors, until often nothing but the type genus or type species remains of the original group.

I have discussed the question of family nomenclature with the Secretary to the International Commission on Zoological Nomenclature, who informs me that it was decided by the International Congress of Zoology at its meeting held in Paris in July, 1948 that the whole question of the rules governing the nomenclature of families shall be the subject of a special report, with recommendations, to be prepared in consultation with specialists, for consideration by the Commission and the Congress at the meeting to be held in Copenhagen in 1958. The Secretary is anxious to receive suggestions from specialists regarding particular aspects of this problem which it may be thought should be dealt with in the revision of Articles 4 and 5 at the Copenhagen Congress. Meanwhile, as the Secretary points out, the whole question of the rules governing the nomenclature of families must be regarded as *sub judice*. Pending the Copenhagen revision, the existing rules remain in force unaltered, and the Secretary to the Commission authorizes me to state that, in his personal opinion, the procedure here adopted is in agreement with the rules as they exist at present.

Superfamilies.—The category "Superfamily" is not at present recognized in the Rules, but it is reasonable to apply to the nomenclature of this category the provisions of the rules governing the nomenclature of families, so far as they are relevant. The termination *-aceae*, here used, is that recommended for use in the forthcoming international Treatise on Invertebrate Paleontology, and adopted by Buckman for ammonite superfamilies many years ago (e.g., Type Ammonites, 1926, vol. vi, pp. 20 ff.), though the form *-acea* is more usual.

I have attributed the name of a superfamily to the first author by whom that name was so published, whereas in the case of families and subfamilies I have attributed the name to the first author to introduce the group name as the name of either a family or a subfamily. Provided the groupings proposed by an author are of higher order than families, they need not have been called by him superfamilies; for such details of terminology have varied from time to time. For instance Wedekind (1917, Palaeontographica, vol. lxii, p. 103) grouped his families in a number of larger units which he called Suborders and Sections, using the terminations *-acea* and *-oidea* respectively. From their form and manner of presentation these are valid groupings of higher-than-family status and are here adopted as superfamilies.

It follows, by analogy, from Opinions 133

and 141 that the superfamily Harpoceratacеae Wedekind 1917 is not invalidated because Harpoceratidae Neumayr 1875 is not the oldest family included in it but has to be subordinated as a subfamily to Hildoceratidae Hyatt 1867; and that the superfamily Perisphinctaceae Wedekind 1917 is not invalidated because Aspidoceratidae Zittel 1895 is an older-established family than Perisphinctidae Hyatt 1900.

By analogy from the rules governing the names of families I have adopted as superfamily name Eoderoceratacеae nov., on the assumption that when Spath in 1929 emended the family Deroçeratidae Hyatt 1867 (on account of *Deroceras* having been preoccupied) to Eoderoceratidae Spath 1929, this automatically emended the superfamily Deroceratida Spath 1926; and consequently I have not adopted instead the unfamiliar superfamily name Xipheroceratida Spath 1929.

THE PROPOSED CLASSIFICATION

(Numbers refer to explanatory notes on pp. 359–364)

ORDER AMMONOIDEA

Suborder Phylloceratina Hyatt 1900 (as superfamily)

Superfamily Phylloceratacеae Hyatt 1900
- Family Phylloceratidae Zittel 1884
  - Subfamily Phylloceratinae Zittel 1884
  - Subfamily Calliphylloceratinae Spath 1927
- Family Juraphyllitidae[1] (Spath 1927) nov. (= Rhacophyllitinae Spath 1927)

Suborder Lytoceratina Hyatt 1889

Superfamily Lytoceratacеae Buckman 1894
- Family Pleuroacanthitidae[2] Hyatt 1900
  - Subfamily Pleuroacanthitinae Hyatt 1900
  - Subfamily Analytoceratinae Spath 1927
- Family Ectocentritidae Spath 1926
- Family Derolytoceratidae Spath 1927
- Family Lytoceratidae Neumayr 1875 (Syn. Thysanoidae[3] Hyatt 1867)
  - Subfamily Lytoceratinae Neumayr 1875
  - Subfamily Hemilytoceratinae Spath 1927
  - Subfamily Megalytoceratinae Spath 1927
  - Subfamily Alocolytoceratinae Spath 1927
- Family Nannolytoceratidae Spath 1927

Superfamily Spiroceratacеae[4] nov.
- Family Spiroceratidae Hyatt 1900
- Family Arcuceratidae nov.

Suborder Ammonitina Hyatt 1889

Superfamily Arietitaceae (Buckman, 1905) nov. (Ammonitacea Buckman 1905; including Psiloceratoidea Wedekind 1917)
- Family Psiloceratidae Hyatt 1867 (syn. Caloceratidae[5] Buckman 1906)
  - Subfamily Psiloceratinae Hyatt 1867
  - Subfamily Alsatitinae Spath 1924 (syn. Proarietitinae Lange 1941)

[1] *Juraphyllites* Muller (1939, Jour. Paleontology, vol. 13, p. 537) replaces the Liassic *Rhacophyllites* auct., the type species of *Rhacophyllites* being the Triassic *Am. neojurensis* Quenstedt, desig. J. Perrin Smith, 1927. Juraphyllitinae includes *Tragophylloceras* Hyatt, the systematic position of which has been so much debated (see Spath, 1936, Quart. Journ. Geol. Soc. London, vol. 92, p. 439).

[2] Pleuracanthitidae Hyatt, but the type genus is *Pleuroacanthites* Canavari 1883.

[3] Thysanoidae Hyatt (1867) is based on *Thysanoceras* Hyatt (1867) (type species *T. orbignyi* Buckman, desig. Buckman 1905), which is a subjective synonym of *Lytoceras* Suess 1865 (type by orig. desig. *Am. fimbriatus* J. Sowerby; see Int. Com. Opinion 130).

[4] Spiroceratids (uncoiled ammonoids) occur in the Middle Bajocian in Sinai and the Aalenian in Switzerland and therefore cannot be, as usually supposed, uncoiled parkinsonids. They and *Arcuceras* Potonié (1929, Jahrb. Preuss. Geol. Landesanst. 50, p. 225) from the Middle Lias are here provisionally regarded as independent offshoots from Lytoceratina, analogous with the uncoiled Cretaceous forms. Spiroceratids persist with little change from Middle Bajocian to Callovian and the idea that the Callovian forms (*Parapatoceras*) originated independently from other Ammonitina has been disproved by Potonié. *Strenoceras* may be a coiled spiroceratid.

[5] Caloceratidae was proposed by Buckman on the mistaken assumption that *Psiloceras* was preoccupied.

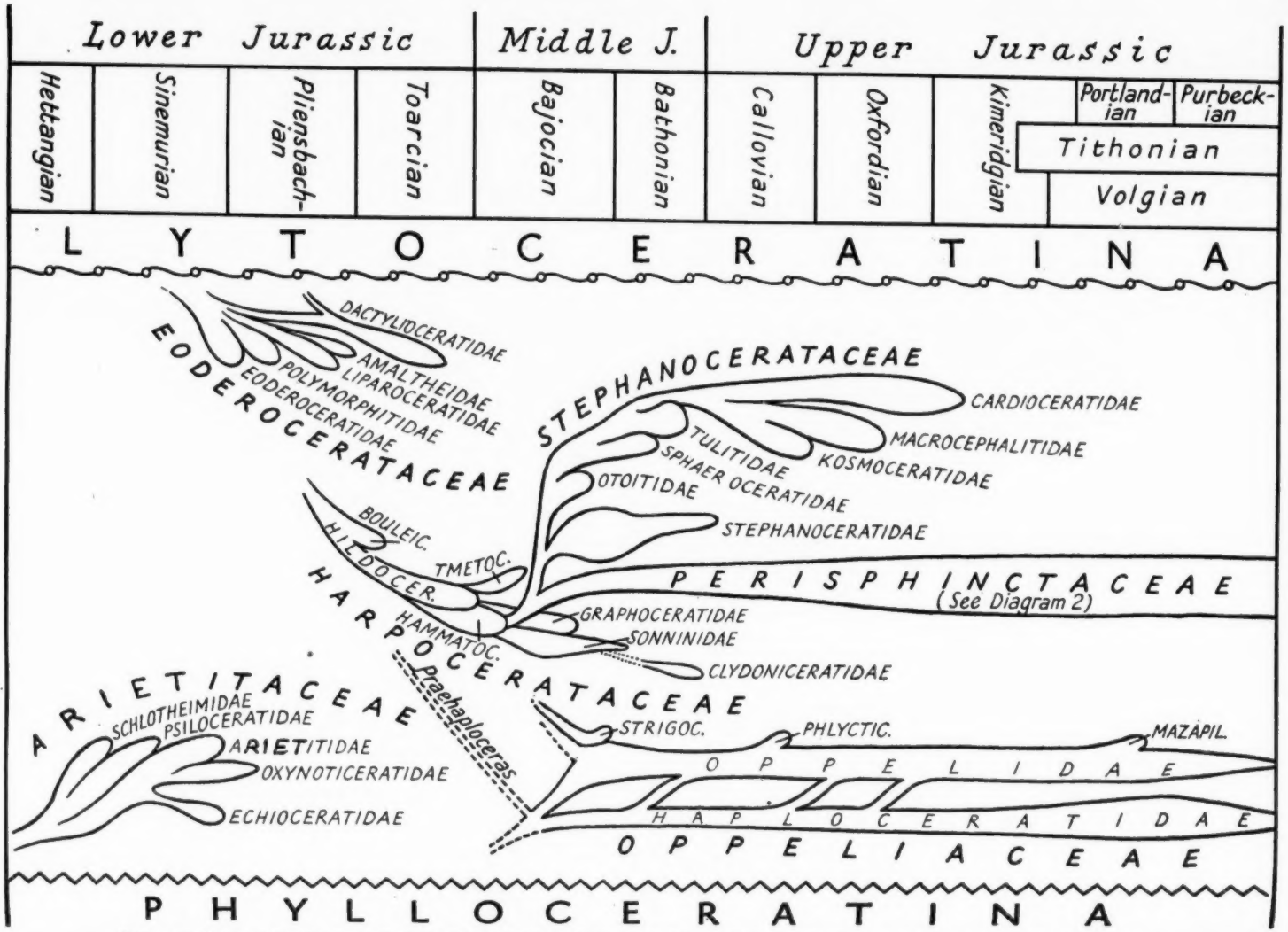

FIG. 1.—Illustrating the supposed relationships of the Jurassic Ammonites to the Lytoceratina and the Phylloceratina.

Family Schlotheimidae Spath 1923 (syn. Angulatidae[6] Hyatt 1874)
Family Arietitidae Hyatt 1874 (syn. Discoceratidae[7] Hyatt 1867)
Subfamily Arietitinae[8] Hyatt 1874
Subfamily Asteroceratinae Spath 1946
Subfamily Arnioceratinae Spath 1924
Subfamily Agassiceratinae Spath 1924
Subfamily Cymbitinae Buckman 1919
Family Oxynoticeratidae[9] Hyatt 1874
Family Echioceratidae Buckman 1913
Superfamily Eoderocerataceae nov. [Spath 1926] (=Deroceratida[10] Spath 1926)
Family Eoderoceratidae Spath 1929 [Hyatt 1867]
Subfamily Eoderoceratinae Spath 1929 (Syn. Deroceratidae[10] Hyatt 1867)
Subfamily Xipheroceratinae Spath 1925
Subfamily Hemimicroceratinae Spath 1929 (Syn. Microceratidae Spath 1926)
Subfamily Phricodoceratinae Spath 1928
Family Polymorphitidae Haug 1887
Subfamily Polymorphitinae Haug 1887
Subfamily Acanthopleuroceratinae[11] nov. [Hyatt 1867] (Syns. Cycloceratidae Hyatt 1867, Tropidoceratidae Hyatt 1900)
Family Liparoceratidae Hyatt 1867 (Syn. Aegoceratidae Neumayr 1875)
Family Amaltheidae[12] Hyatt 1867
Family Dactylioceratidae[12] Hyatt 1867
Superfamily Harpoceratacea Wedekind 1917
Family Hildoceratidae Hyatt 1867
Subfamily Seguenziceratinae Spath 1924
Subfamily Hildoceratinae Hyatt 1867
Subfamily Harpoceratinae Neumayr 1875
Subfamily Grammoceratinae Buckman 1904
Family Tmetoceratidae[13] Spath 1936
Family Bouleiceratidae[14] nov.
Family Hammatoceratidae Buckman 1887
Subfamily Hammatoceratinae Buckman 1887
Subfamily Phymatoceratinae Hyatt 1900 (Syn. Hauginae Buckman 1905)
Family Sonninidae[15] Buckman 1892

[6] Angulatidae Hyatt is invalid because it has no type genus, being formed on the species *Ammonites angulatus* Schlotheim.

[7] *Discoceras* Hyatt 1867, preoccupied. Hyatt substituted Arietidae for Discoceratidae.

[8] Type species of *Arietites* Waagen 1869 by monotypy is *A. bucklandi* J. Sowerby (refigured Buckman, 1919, Type Ammonites, vol. iii, pl. CXXXI), but it is not a synonym of *Coroniceras* Hyatt 1867, of which the lectotype species is *A. kridion* Hehl in Zieten, designated Bonarelli, 1900 (Pal. Italica, V, p. 58) (objective synonym *Arnioceratoides* Spath 1922). Arietitinae as here restricted is the same as Ammonitidae Spath (1924, Proc. Geol. Assoc., vol. 35, p. 202), and Arietitidae as here used is the same as Ammonitidae Buckman (1919, Type Ammonites, vol. ii, p. B, and 1920, vol. iii, p. 13). These were artificial "revivals" entirely different from the family Ammonitidae Owen 1836, a group almost coincident with the present order Ammonoidea (family Ammonitea de Haan 1825). The type species of *Ammonites* Bruguière 1789 is *A. bisulcatus* Bruguière, designated Meek 1876 (U. S. Geol. Survey Territories, vol. 9, p. 446), and the lectotype of *A. bisulcatus* is a figure in Lister (1678, Cochlitarum Angliae, pl. vi, fig. 3), designated Buckman 1923 (Type Ammonites, vol. iv, pp. 56–57). This is probably a Lower Sinemurian Arietitid from Bugthorpe Beck, Yorkshire, but it is generically unidentifiable. Accordingly an application has been made by the writer to the International Commission on Zoological Nomenclature to place *Ammonites* Bruguière on the Official Index of Suppressed and Invalid Generic Names. Attempts by Buckman to reintroduce it in a restricted sense, after its universal abandonment as the generic name for all ammonites, have led to much confusion.

[9] Oxynotidae Hyatt 1874, which according to the Rules automatically becomes Oxynoticeratidae, from the type genus *Oxynoticeras* Hyatt 1874.

[10] *Deroceras* Hyatt 1867, preoccupied, was replaced by *Eoderoceras* Spath 1925.

[11] *Cycloceras* Hyatt 1867, preoccupied, was replaced by *Acanthopleuroceras* Hyatt 1900.

[12] Amaltheoidae, Dactyloidae Hyatt, 1867, first rectified to Amaltheidae by Fischer 1882, and Dactylioceratinae by J. P. Smith, 1913. Dactylioceratidae includes (as a genus) Coeloceratidae Haug 1910.

[13] Vacek's comparison of *Tmetoceras* with *Catulloceras dumortieri* (Thiollière) and Haug's comparison of that with *Dumortieria levesquei* (d'Orbigny) lead to the conclusion that *Tmetoceras* is of Hildoceratid descent, and Spath placed it as a subfamily of Hildoceratidae.

[14] Bouleiceratidae nov. for *Bouleiceras* Thevenin 1906, and *Paroniceras* Bonarelli 1893, with ceratitic sutures.

[15] Sonninidae includes Poecilomorphidae and Zurcherinae Hyatt 1900.

PHYLLOCERATINA

FIG. 1—Illustrating the supposed relationships of the Jurassic Ammonitina to the Lytoceratina and the Phylloceratina

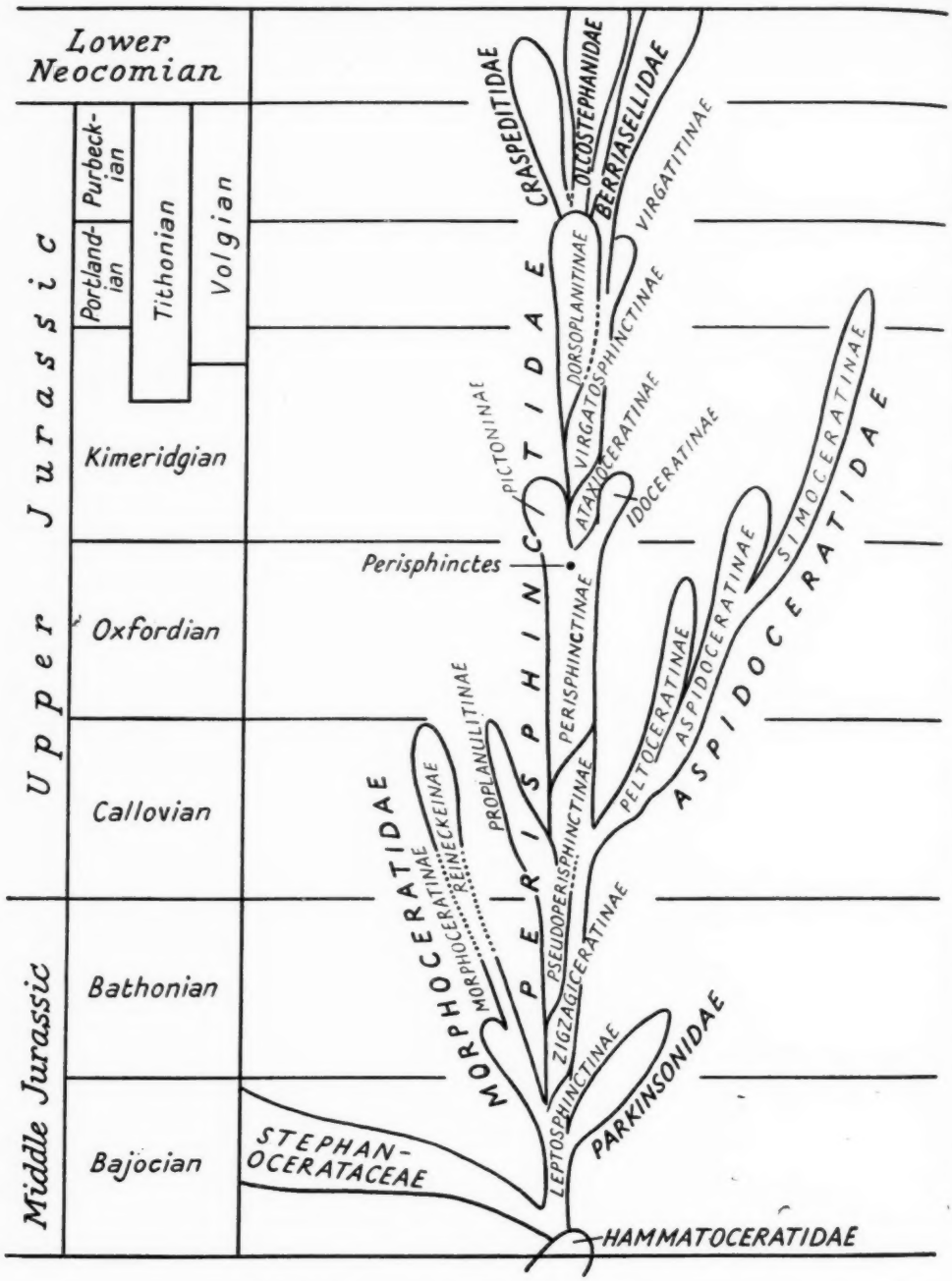

FIG. 2—Enlarged view of the Perisphinctaceae.

Family Graphoceratidae Buckman 1905
- Subfamily Graphoceratinae[16] Buckman 1905
- Subfamily Darelleinae Buckman 1905
- Subfamily Leioceratinae Spath 1936

Family Clydoniceratidae Buckman 1924

Superfamily Oppeliaceae Buckman 1924

Family Strigoceratidae Buckman 1924

Family Haploceratidae Zittel 1884 (Syn. Lissoceratidae Douvillé 1884)

Family Oppelidae Bonarelli 1893
- Subfamily Oppelinae[17] Bonarelli 1893
- Subfamily Hecticoceratinae Spath 1925
- Subfamily Ochetoceratinae Spath 1928
- Subfamily Distichoceratinae Hyatt 1900 (Syn. Bonarellinae[18] Spath 1925)
- Subfamily Taramelliceratinae Spath 1928
- Subfamily Streblitinae Spath 1925

Family Phlycticeratidae[19] Spath 1928

Family Mazapilitidae Spath 1928

Superfamily Stephanocerataceae Wedekind 1917 (Syn. Stepheoceratacea Buckman 1919)

Family Stephanoceratidae Neumayr 1875 (Syn. Stepheoceratidae[20] Buckman 1898)

Family Otoitidae Mascke 1907

Family Sphaeroceratidae[21] Buckman 1920

Family Tulitidae Buckman 1921

Family Macrocephalitidae[22] Buckman 1922

Family Kosmoceratidae Haug 1887

Family Cardioceratidae Hyatt 1892
- Subfamily Cadoceratinae Hyatt 1900
- Subfamily Pachyceratinae Buckman 1918
- Subfamily Cardioceratinae Hyatt 1892

Superfamily Perisphinctaceae Wedekind 1917

Family Perisphinctidae Hyatt 1900

Main Stock:
- Subfamily Leptosphinctinae[23] nov
- Subfamily Zigzagiceratinae Buckman 1920
- Subfamily Pseudoperisphinctinae[24] Schindewolf 1925
- Subfamily Perisphinctinae Hyatt 1900
- Subfamily Ataxioceratinae Buckman 1921
- Subfamily Virgatosphinctinae[25] Spath 1923
- Subfamily Dorsoplanitinae nov.[26] [Schindewolf 1925] (Syn. Pavlovinae Spath 1931)

[16] Graphoceratinae includes Hyatteinae and Lucyinae Buckman 1905 and Ludwigellidae Spath 1928.

[17] Oppelinae includes Hebetoxyitidae Buckman 1924?

[18] *Bonarellia* Cossmann 1898 was proposed as substitute for *Distichoceras* Munier-Chalmas 1892, on the mistaken assumption that the latter was preoccupied.

[19] *Phlycticeras* Hyatt 1900, Callovian, is a remarkable homoeomorph of *Strigoceras* Quenstedt 1886, Bajocian, but can hardly be directly related. The somewhat similar *Micromphalites* Buckman 1923, Bathonian, is now classed in Clydoniceratidae, Harpoceratacеae.

[20] *Stepheoceras* Buckman 1898, proposed as substitute for *Stephanoceras* Waagen 1869, on the mistaken assumption that the latter was preoccupied. See Spath 1944, Geol. Mag., vol. 81, p. 230.

[21] *Sphaeroceras* Bayle 1878, is preoccupied by *Sphaeroceras* Hope 1840, for a beetle, but since coleopterists inform me that *Sphaeroceras* Hope is an objective synonym of *Globicornis* Latreille 1829, and has hardly ever been used, and cannot be used again, I have applied to the International Commission on Zoological Nomenclature to have it placed on the Official Index of Rejected and Invalid Generic Names, and *Sphaeroceras* Bayle 1878, placed on the List of Valid Generic Names.

[22] Macrocephalitidae includes Mayaitidae and Eucycloceratidae Spath 1928, and Grayiceratidae Spath 1925.

[23] Leptosphinctinae nov. for the Middle and Upper Bajocian Perisphinctids, *Leptosphinctes* Buckman and its allies, often with coronate (tuberculate) nuclei, queried by Buckman as Parkinsonidae.

[24] Pseudoperisphinctinae Schindewolf, based on *Pseudoperisphinctes* Schindewolf 1923, of which the type species by monotypy is *Per. rotundatus* Roemer (1911, pl. 8, fig. 2 lectotype), includes Grossouvrinae Spath 1930.

[25] Virgatosphinctinae is here considered to include Pseudovirgatitinae Spath 1931 as indistinguishable.

[26] *Polytosphinctes* Schindewolf 1925 is an objective synonym of *Dorsoplanites* Semenow 1897; therefore Polytosphinctinae Schindewolf 1925 becomes automatically Dorsoplanitinae nov.

Offshoots
- Subfamily Proplanulitinae Buckman 1921
- Subfamily Pictoninae[27] Spath 1924
- Subfamily Idoceratinae Spath 1924
- Subfamily Virgatitinae Spath 1923
- Family Parkinsonidae Buckman 1920
- Family Morphoceratidae[28] Hyatt 1900
  - Subfamily Morphoceratinae Hyatt 1900
  - Subfamily Reineckeinae[29] Hyatt 1900
- Family Aspidoceratidae[30] Zittel 1895
  - Subfamily Aspidoceratinae Zittel 1895
  - Subfamily Peltoceratinae Spath 1924
  - Subfamily Simoceratinae Spath 1924

Terminal forks
- Family Berriasellidae[31] Spath 1922
  - Subfamily Berriasellinae Spath 1922
  - Subfamily Himalayitinae Spath 1925
  - Subfamily Paraboliceratinae Spath 1928
  - Subfamily Neocomitinae Spath 1924 (Cretaceous)
- Family Craspeditidae Spath 1924
- Family Olcostephanidae[32] Haug 1910
  - Subfamily Olcostephaninae Haug 1910 (Cretaceous)
  - Subfamily Spiticeratinae Spath 1925
  - Subfamily Polyptychitinae Spath 1924 (Cretaceous)

[27] Pictoninae Spath 1924 includes Raseninae Schindewolf 1925 and Aulacostephaninae Spath 1924 (the closely interlinked genera *Ringsteadia*, *Pictonia*, *Rasenia*, *Aulacostephanus* etc. and their subgenera).

[28,29] The likeness between the Lower Bathonian Morphoceratid *Ebrayiceras pseudo-anceps* and the Callovian *Reineckeia anceps* (pointed out by Ebray in 1864) is so close that there is little doubt that Reineckeidae are derived from *Ebrayiceras*. An example of how such gaps are always liable to be bridged is the finding by Guillaume (1927, C. R. Soc. géol. France, no. 17, p. 217) of an *Ebrayiceras* in the Middle Bathonian of Normandy. The earliest known Morphoceratid is the Bajocian *Dimorphinites*, of which the venter has no furrow or smooth band, and the prevalent constrictions of this and *Morphoceras* point to their Perisphinctacean origin; but all forms show points of convergence to Stephanocerataceae.

[30] The possibility that Peltoceratinae originated from Reineckeinae requires further investigation.

[31] Berriasellidae Spath 1922 is included by Roman in an invalid family Palaeohoplitidae Roman 1938, which has no status in nomenclature because there is no type genus.

[32] Misspelt Holcostephanidae by Haug (1910, Traité, ii, pp. 1166, 1167), but the genus is *Olcostephanus* Neumayr 1875. First rectified to Olcostephanidae by Pavlow 1913.

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BRACHIOPODA AND STRATIGRAPHY OF THE APLINGTON FORMATION OF NORTHERN IOWA

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ABSTRACT—The Aplington formation, formerly included with the Sheffield beds, is distinguished and type section indicated. Faunal comparisons apparently indicate that the age of the formation is Lower Mississippian. Three new genera of brachiopods, one productid and two spiriferids, are diagnosed. Seventeen species are described and illustrated, all as new forms.

INTRODUCTION

IN NORTH central Iowa in Franklin and Butler counties occurs a series of beds mostly dolomitic and carrying a distinctive fauna that has not been seen elsewhere in the state. Formerly these strata have been included in the Sheffield shale but they seem to differ significantly enough in lithology and fauna to merit separate stratigraphic designation as the Aplington formation. The name is that of the town of Aplington in southern Butler County where the best section is exposed in recent quarrying operations.

The beds comprising the Aplington formation have been mentioned a number of times by geologists, generally as a part of the Sheffield shale. Beyer and Williams referred the beds in question in the region of Sheffield, Franklin county, to the Lime Creek shale and gave a section located one half mile south of the Minneapolis and St. Louis Railway station. Only shaly beds were noted at the brickyard but 1–4 inches of fossiliferous limestone was said to be exposed in a railroad cut to the east. This is probably the basal bed of the Aplington.

Williams (p. 478) referred to the same brickyard pit and noted a roadcut in section 10, Ross Township, in the same county. Strata in both places were referred to the Hackberry (Lime Creek). He noted the occurrence of dolomite and yellow magnesian shale with chert in section 7, West Fork Township. Several species of fossils were named and the beds were considered to be of Owen age. A bed of dolomite resting on blue shale was located by Williams (p. 486) in section 10, Geneva Township of the same county, just east of the bridge over Maynes Creek, and several fossils, among them *Athyris prouti*, were listed. The beds were referred to the Kinderhook. These and the preceding are parts of the Aplington.

Arey mentioned the occurrence of Lime Creek shales, a half mile north of Aplington in Butler County, and listed several fossils, among them *Atrypa reticularis*, *Atrypa aspera* and *Bellerophon pelops*. This locality is identical with the type section of the Aplington. A special search was made for the fossils named but none was secured. It seems probable that Arey had found the Aplington beds and some of its fossils instead or else had secured his fauna from a different locality.

Fenton in 1919 (p. 355) first used the name Sheffield in applying it to the blue shale (Hamilton of Webster) in the lower part of the Lime Creek beds at Hackberry Grove, Cerro Gordo County, Iowa. He indicated no type section for his proposed formation and gave few details regarding it. Since he chose the name Sheffield we have no other course than to assume that the terrane was exposed at that place. A blue shale is exposed in the brickyard pit south of town as mentioned by Beyer and Williams who considered it to be Lime Creek. As Sheffield is more than twenty miles away from Hackberry Grove, we must assume that Fenton thought the blue shale in each locality was the same formation. Otherwise the name would be exceedingly inappropriate and misleading. Webster and Fenton's map (1919) shows Hackberry around the city of Sheffield.

Thomas (p. 116) called attention to the fact that Fenton had apparently applied

the name, Sheffield, to two distinct shales and accordingly named the older one exposed at Hackberry Grove and Rockford, the Juniper Hill shale. Thus, Sheffield remains to designate the shale at Sheffield and is both the logical and appropriate term.

Van tuyl (p. 91) referred the blue shale, now called Sheffield, to the Kinderhook. He included therein the brownish dolomite above, carrying a few fossils of presumed Chouteau affinities, because of the absence of evidence of a disconformity between it and the shale below.

Fenton and Fenton (1924) in a study of the fauna of the Hackberry beds (p. 57) discussed the basal blue shale briefly and referred to it as the Sheffield formation.

Laudon (1931) discussed the Sheffield shale and dolomite (Aplington) briefly and listed the fossils as identified by him. On the basis of the fauna the formation was definitely correlated with the Chemung of New York. In a study of the Kinderhook beds (1931, p. 346) he stated that the Sheffield was overlain by Maple Mill shale and English River in the southeast part of the state and by the Hampton in the north. A composite section of the Sheffield and Aplington was included (p. 386).

Moore (p. 240) stated that the Sheffield was probably equivalent to the Hannibal along with the Maple Mill and English River, and probably Kinderhook in age. Laudon (1935, p. 246), however, maintained that the Sheffield was late Upper Devonian and named a few fossils in support of his contention.

Cooper (p. 1780) said "it seems clear that the Sheffield [including Aplington] is of Cassadaga age and not Kinderhook as claimed by some."

Youngquist and Peterson described the conodonts of the Sheffield (restricted) and stated that the formation is probably Upper Devonian, chiefly on the basis of the occurrence of the genus *Icriodus* in the shale.

In summary the Aplington has generally been included in the Sheffield formation although not as originally defined. The Aplington and Sheffield have been considered by some geologists to be basal Mississippian and by others to be Upper Devonian.

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation of the courtesy given him by the director of the Iowa Geological Survey, H. G. Hershey, who provided opportunity to study the Aplington and gave permission to use the facts thus obtained. The conclusions advanced here are those of the writer, however, and do not necessarily imply approval by the Survey.

CHARACTERISTICS OF THE FORMATION

The Aplington is dominantly a dolomite but contains a subordinate amount of shale and limestone at the base. The dolomite is generally brownish to buff in color, soft for the greater part but in places tough and resistant, especially near the base. The layers are usually massive but stratification planes are often not evident. Thin, irregular, often discontinuous seams of chert, varying in thickness from 0–4 inches, occur at intervals in the upper portion of the formation. The chert is white to gray in color, generally carries abundant fossils and often is weathered to a chalky consistency. In places chalcedonic nodules and geodes may occur in the dolomite. The basal dolomitic portion also usually displays numerous cavities from which the limy fossils have been dissolved.

In a number of localities the basal member of the Aplington is a hard limestone almost completely composed of shells and shell fragments and approaching a coquinite in lithology. The beds vary in thickness from two to ten feet and are generally massive although weathering into thin irregular layers. In several places a two foot bed of shale intervenes between the limestone and the upper dolomite member but elsewhere the dolomite may lie directly on the limestone. Complete fossils are few and difficult to extract from the limestone matrix but the few that have been secured are the same species as those in the dolomite above. Consequently this limestone is considered to be the basal member of the Aplington.

The type section is situated about a half mile directly north of Aplington, Butler County, on the west side of the road. Quarry operations have been extensive and a considerable area is at present (1947) uncov-

ered. All members are available except the basal limestone which does not occur here. The Sheffield shale was formerly visible but the pit exposing it is now filled in. The section given below may not be completely available to observers in the future.

Type section of the Aplington Formation
Aplington, Iowa

Aplington	Feet
7. Dolomite, soft, yellow, thin-layered, a crinoidal zone near base.	4–5
6. Dolomite, yellow, soft, fossiliferous, *Camarotoechia, Spirifer, Arctospirifer, Schellwienella, Cleiothyridina,* and productids.	3
5. Dolomite, yellow, soft, capped by a cherty layer, 1–3 in. thick in middle portion. (Large productid zone.)	3
4. Dolomite, yellow, softer than that below, chert at top, numerous small productids and a small form of *Cleiothyridina* near top. (Small productid zone.)	4
3. Dolomite, soft, yellow, carrying numerous Spirifers with white shells, in three heavy beds. (*Spirifer* zone.)	4
2. Dolomite, massive, dark yellow brown, tough, many holes, fossils abundant, white, weathering with hollow shells, *Cleiothyridina, Spirifer,* large productids as molds, *Schellwienella.* (*Cleiothyridina* zone.)	3
1. Dolomite, massive, yellow-brown with reddish phases, especially at bottom, carrying small geodes, hollows, numerous fossil molds.	3–4
Sheffield shale	
Shale, yellowish where weathered, blue elsewhere, exposed for three or four feet.	

On the south line of Cerro Gordo County in section 34, township 8, Pleasant Valley, a large quarry has been opened to obtain agricultural lime for which the considerably weathered dolomite is suitable and easily prepared. The following section is exposed.

Aplington	Feet
5. Dolomite, buff yellow, much weathered, soft.	6
4. Dolomite, yellow, massive with chert seams, chalcedony nodules and geodes.	6
3. Dolomite, dark brown, soft, with chert seams, fossiliferous, many large silicified productids near base.	4

About two blocks west in the south bank of creek the section is continued:

2. Dolomite, massive, dark brown, Sheffield shale tough, fossils as molds.	4
1. Shale, bluish drab, with a layer of dolomite near middle.	8

At Sheffield about a fourth mile south of the Brick and Tile Plant, beds are exposed in a cutting on the east-west road.

Aplington	Feet
2. Dolomite, yellowish with chert seams thin-bedded at base, fossils.	6
Sheffield	
1. Shale, blue, carrying geodes.	20

In bed number 2 are fossils of the higher zones of the type section. The lower zones apparently never were deposited in the immediate region.

In West Fork Township of Franklin County in sections 7, 8, 17, and 18 occurs an outlier of basal Mississippian strata surrounded by Devonian and alluvium or till. These beds form a conspicuous ridge known locally as Dry Hill. Basal beds of the Aplington are exposed in the SE ¼ of section 7.

Aplington	Feet
3. Shale, gray	2
2. Limestone, more or less crinoidal, thin layered, fossiliferous and resembling a coquina.	2–4
Sheffield	
1. Shale, blue.	

Another interesting section showing beds above the Aplington occurs in the middle of section 2, Geneva Township, Franklin County. Here an excavation for road and agricultural material has been made in the east side of the road.

Louisiana limestone	Feet
3. Limestone, white, lithographic, brittle, thin-bedded, fossiliferous.	4
Chapin	
2. Limestone, dolomitic, oolitic, fossiliferous.	12
Aplington	
1. Dolomite, yellow, much weathered, carrying molds of typical fossils, a little chert.	8

The contact of the Aplington with the Chapin is also seen in the roadside one mile west of Chapin in the southwest corner of section 29, Ross Township, Franklin County. Just south a couple of rods is a quarry revealing the type section of the Chapin formation. In the south borrow ditch Aplington lies below the Chapin with what is apparently conformable contact.

The Chapin-Aplington contact is seen again about two blocks north of the abandoned schoolhouse near the middle of the section line between sections 13 and 14 in Geneva Township, Franklin County.

Chapin	Feet
3. Limestone, oolitic, fossiliferous, seemingly conformable with beds below.	2
Aplington	
2. Dolomite, soft, yellow, fossiliferous, fossils silicified and typical.	20
Sheffield	
1. Shale, blue, mostly covered, visible in roadside ditch.	15

Several blocks east of the same schoolhouse the basal crinoidal limestone with *Cleiothyridina* lies on the Sheffield shale. This same basal limestone is seen in an abandoned quarry southeast of Hartsell, Franklin County, in the NW ¼ of section 28, Ingham Township. The section follows:

Aplington	Feet
3. Dolomite, much weathered with chert seams and typical fossils.	5
2. Limestone, crinoidal, white, grading into beds below.	3–4
1. Limestone, yellowish, massively bedded, coarse grained, subdolomitic, crinoidal.	4

In the west ditch of the road one-fourth mile east, blue Sheffield shale is seen to underlie the limestone.

EXTENT AND RELATIONS

The Aplington formation outcrops in a narrow belt extending from the middle of the south line of Cerro Gordo County through Richland, Mott, Ingham and northern Geneva townships in Franklin County into the southwest corner of Butler County. Here a large part of Washington and smaller parts of Madison and Monroe townships are included in the outcrop area. The belt varies in width but is generally several miles wide. It undoubtedly extends northward into Cerro Gordo County and southward into Grundy County but its surface extent in either county cannot at present be checked by exposures. The subsurface distribution of the formation has not yet been ascertained but the terrane may possibly extend as far south as northern Tama County. It is apparently unknown elsewhere in the state.

The Aplington lies on the Sheffield everywhere as far as known with apparent unconformability. The unconformity is known by the fact that at various localities different horizons of the formation lie on the shale. This relationship is demonstrated in the sections given above. The only hard rock strata seen above the Aplington in the field belong to the Chapin beds. In several localities where the contact is visible it appears to be conformable although there is a somewhat marked lithologic and faunal change. Both formations are dolomitic, however, their bedding planes are parallel and if the contact be disconformable, it certainly does not appear to be inter-systemic and is probably nothing more than inter-formational.

SUMMARY

The Aplington is chiefly a dolomite with seams of chert and attains a thickness of about 25–30 feet. A coquina-like limestone two to six feet thick may occur at the base and in places may be separated from the dolomite above by a thin bed of shale. As various zones of the Aplington lie on the Sheffield, relations with that formation are probably unconformable. The Aplington appears to be conformable with the Chapin beds above wherever the contact is seen.

FAUNA OF THE APLINGTON

The fauna is not an abundant one either in species or individuals. Locally some forms may be common, where extensive quarrying operations have revealed them over a considerable area. The apparent scarcity of specimens of many forms in most localities may be due to unfavorable living conditions on the sea bottom as prevailingly dolomitic beds were deposited. Except in the basal bed the fossils are generally most common in or confined to chert seams. This condition may be due to the greater permanency of the chert and its resistance to solution as most of the fossils elsewhere are in the form of internal and external molds. The latter escape notice easily, especially where the beds are strongly weathered.

The majority of the fossils are silicified in a peculiar manner. Generally the interior is filled with chalklike silica while the shell may still be calcareous. In many instances the shells have been silicified but the development of beekite rings has destroyed the finer surface markings. In the second zone above the base of the type section most of the shells are silicified but their interiors are not filled with silica but with dolomite,

or are hollow. In the basal bed many of the productids are similarly preserved but the major part of them are in the form of molds.

The fauna is dominated by the brachiopods which include about fifteen identifiable species. There are probably several others but the nature of the preservation or the incompleteness of the specimens do not allow description. No orthoids and only one strophomenoid are present. The productoids are common individually and are probably the most abundant group. The five species are placed in four genera, one new, equally divided among the Productinae and Strophalosiinae. *Camarotoechia* is the only rhynchonellid genus and is represented by three species. Thus far no terebratuloid has been discovered in the formation. The spiriferids have four genera, two of them new, and five species are described, and there are probably several others. *Cleiothyridina* with two species is the only athyroid genus in the fauna.

The lone coral is an auloporoid and is moderately common individually. Encrusting, branching and hederelloid forms represent the bryozoans. An *Archaeocidaris* spine and plate and numerous crinoid columnals are the only echinodermal remains recovered. Several poorly preserved pelecypods and a portion of an ammonoid represent the mollusks. The vertebrate fossils include several dermal plates of fishes.

CORRELATION OF THE APLINGTON

As noted above the Aplington (included in the Sheffield) has been correlated by Laudon with the Chemung of New York. Some of the genera are the same in both terranes and several species appear to be similar in some respects. Laudon's correlation was based mainly on his identification of the following species in the Aplington: *Orthotetes chemungensis* var. *arctostriata*, *Productella lacrymosa*, *Productella stigmata*, *Productella costatula*, *Productella onusta*, *Camarotoechia sappho*, *Camarotoechia contracta*, *Spirifer disjunctus* and *Athyris angelica*. The writer however has been unable to identify these species with any of the forms at hand.

The orthotetoid shell is a member of *Schellwienella*. *Schellwienella arcotostriata* Hall has not, as far as known to the writer been accurately illustrated and described. Hall described several varieties but repeated Conrad's brief description of the original. Our form does not appear to be *Schellwienella arctostriata* as it is twice as large and resembles Mississippian forms as much as it does Devonian examples of the genus. *Schellwienella* generally, as far as studied by the writer, does not possess many outstanding characteristics which enable one to readily distinguish various species unless specimens are completely and exceptionally well preserved.

The genus *Productella* is characterized by well developed cardinal areas in both valves, teeth and sockets, spines on the pedicle valve and no costae on either valve. The productids from the Aplington either lack areas or have them so weakly developed that they are best described as linear. In some examples wear, weathering or movement may make it appear that areas are present but exceptionally well preserved forms show them to be absent. Consequently the productelloid species of the Aplington appear to be in a later stage of evolutionary development and are considered to be distinctly separable from that genus.

One species plainly belongs to a new genus of the Productellinae; it has spines on the brachial valve and a low area but is otherwise similar to *Productella*. The other form of this subfamily apparently agrees with the genus *Leioproductus* since it too lacks areas. The other productids belong to the Strophalosiinae and therefore are not members of *Productella*. Consequently there appears considerable doubt that any of the productellids of the Aplington are conspecific with any of the species of *Productella* mentioned by Laudon. Some of the latter occur high in the Upper Devonian and may be close to our species in several ways. Until they are more thoroughly studied and better described, however, comparison with our forms cannot be made satisfactorily at this time.

Our smaller species of *Camarotoechia* do not seem to be very near *Camarotoechia contracta* Hall as described and illustrated by Caster and are here considered as new species. The large *Camarotoechia* resembles *Camarotoechia sappho* to some extent but appears to be specifically distinct. Caster reports mutants in the basal Mississippian

of New York and Pennsylvania and similar forms therefore could be expected in the basal Mississippian of Iowa.

Spirifer disjunctus as described and pictured by Hall is a highly variable species and possibly polyphyletic. Many of the variations are probably evolutionary and possibly correlated with the formation in which the specimens are found. Until a study of the variations and their stratigraphic significance has been made, *Spirifer disjunctus*, as now constituted, has little value as a horizon marker. Caster (p. 71, 1934) reports variants of the *Spirifer disjunctus* gens in the Berea of the Mississippian, therefore, the occurrence of similar forms would not necessarily indicate Chemung Devonian. The genus *Cyrtospirifer* to which *Spirifer disjunctus* belongs apparently has an extended range. Dr. Harrington of the University of Buenos Aires has recently informed me that the genus occurs in the Mississippian of England along with *Spirifer striatus* Martin and that it is known from the Permian as well. The writer (1947) has recently suggested that the Percha shale with its *Cyrtospirifer* is Mississippian.

In any event our species of spiriferids do not seem to be *Cyrtospirifer disjunctus*. One is certainly a true *Spirifer* of the Mississippian type. Two others must be placed in a new genus. Another is *Cyrtospirifer* but its external markings do not allow its identification as *Cyrtospirifer disjunctus*. A third is a member of a second new genus which is not known from the Chemung.

Lastly we do not find any member of the genus *Athyris* in the Aplington. All our athyroids are members of *Cleiothyridina* and possess well developed growth spines. Presence of spines is not mentioned by either Hall or Caster in their descriptions of *Athyris angelica*. Consequently our forms apparently differ generically from *Athyris angelica* as well as differing in shape and in other respects.

The Aplington formation on the basis of the fauna does not appear to be correlatable with the Chemung of New York, nor with other later Devonian formations of that region. Similarity of some of the Aplington species to Devonian species is explainable by the extended ranges of certain genera of brachiopods as *Schellwienella*, *Camarotoechia* and *Cyrtospirifer*, into the Mississippian.

In the basal dolomitic portion of the Aplington, as displayed in the type section, many fossils occur in the form of internal and external molds. Thus the fossils resemble those in the Chemung of New York in which this type of preservation is usual. The resemblance is superficial only and to the writer has little significance and is only coincidental. Similar preservation in terranes as far removed from each other as the Chemung of New York and the Aplington of Iowa scarcely indicates that the beds are contemporaneous.

At the present time as far as known to the writer there is no formation in the Mississippian with which the Aplington may be definitely correlated. It may be chronologically equivalent to some portion of the Meadville stage as described by Caster. Until the faunas of this stage and adjacent beds are made better known, however, this suggested correlation is highly speculative. Apparently in southern Iowa and adjacent areas, its stratigraphic position is in the interval indicated by the unconformity between the English River siltstone and the Louisiana limestone.

AGE OF THE APLINGTON

The Aplington along with the Sheffield formation, from which it is now separated, has generally been regarded as a member of the Kinderhook series of the Mississippian system. This position was unquestioned until Laudon correlated the Sheffield (chiefly on the basis of the Aplington fauna) with the Chemung of the New York Devonian. Youngquist and Peterson have recently indicated that the Sheffield shale is probably Upper Devonian in age, mainly on the basis of the presence therein of the conodont genus *Icriodus*. However the writer does not consider this evidence conclusive, as *Icriodus* has been recovered from the Louisiana limestone which is apparently a Mississippian formation. However as the Aplington lies unconformably on the Sheffield, the age of the latter may not necessarily have great bearing on the age of the Aplington.

The Aplington is here regarded as an early member of the Kinderhook series.

Evidence for this placement of the formation is stratigraphic and faunal. It is associated with definitely Mississippian formations in what appears to be a conformable succession of beds. This is shown in the lower Kinderhook section in Franklin County, Iowa, which is as follows: at the top the Prospect Hill sandstone, a correlative of the Hannibal of Missouri, has an extensive fauna of undoubted Mississippian affinities. Beneath it is the Louisiana limestone (McCraney) carrying *Chonopectus fisheri* (N. and P.), *Linoproductus ovatus* (Hall), *Paraphorhynchus* and others. Below this is the Chapin dolomitic and suboolitic limestone with an extensive fauna as listed by Van Tuyl and Laudon. Distinctive species are *Zaphrentis cliffordana* Ed. and H., *Cyathaxonia arcuatus* Weller, *Leptaena analoga* Phillips, *Productus arcuatus* Hall, *Linoproductus ovatus* (Hall), *Spirifer platynotus* Hall and *Syringothyris newarkensis* Weller and others. This is a definitely Mississippian fauna. The Chapin overlies the Aplington with apparent conformability. The contact is seen at a number of places and shows no erosional or irregular contact. The lithologic change is fairly distinct as the Aplington is more dolomitic and softer, while the Chapin is massively bedded limestone and only dolomitic basally. No evidence of an unconformity at the base of the Chapin as indicated by Laudon was found—the unconformity seems to be at the base of the Aplington instead. The formations mentioned form a conformable succession and therefore appear to be Mississippian throughout.

The Aplington lies on the Sheffield shale which is similar in many ways to the Maple Mill shale ofthe southern part of the state. The Maple Mill may be traced in surface exposures and in wells as far north as northern Tama and Hardin counties, Iowa. Lack of exposures of bed rock in Grundy County and paucity of suitable well sample suites has thus far prohibited the determination of the extent of the two formations and their possible equivalency in this intervening area. There are indications that they may be parts of the same body of shale. If so there would be no doubt as to the position of the Aplington in the Mississippian system as the Maple Mill at Burlington, Iowa, has a Mississippian fauna.

Faunally the evidence bearing on the age of the Aplington is in favor of the Mississippian. The productids are not members of the genus *Productella*, which may be limited, as far as now known, to the Devonian. The absence of cardinal areas in the members of the Productellinae indicates a later evolutionary development than that exhibited by Devonian Productellinae. The members of the Strophalosiinae likewise have no Devonian significance as one genus, *Planoproductus*, has as yet not been recognized in the system.

The camarotoechioids are noncommittal but do not appear to indicate a Devonian age. Several gentes of the genus have a long range in the Upper Devonian and may well extend up into the Mississippian (Caster, p. 124).

The spiriferids are definitely not indicative of the Devonian age of the Aplington but appear distinctly Mississippian. *Spirifer thomasi* is a true *Spirifer* of Mississippian type with its strongly plicate fold and sulcus unlike any species in the Upper Devonian known to the writer.

Arctospirifer and *Liraspirifer* are genera which apparently do not occur in the Devonian of Eastern United States in strata higher than the Chemung. *Arctospirifer* especially seems to a later development in the evolution of the Spiriferids. *Cyrtospirifer* is represented but this genus does not indicate Upper Devonian age as it is recognized in the Mississippian (Caster, 1934, p. 124) in America and in England (Harrington).

The genus *Cleiothyridina* has at least two species with abundant and long spines. Although one species of the genus has been described from the latest Devonian of Montana, the genus is more characteristic of the Mississippian. In addition *Archaeocidaris* and *Cladochonus* are Mississippian as far as known.

In summary the Mississippian age of the Aplington is favored by its stratigraphic position in relation to known formations of that system and by its faunal relationships. There is little to suggest the Upper Devonian. None of the diagnostic fossils of that series is present in the Aplington. A few species may resemble Upper Devonian forms but these are members of genera that

are all highly variable and long ranging types which have little stratigraphic significance.

SYSTEMATIC DESCRIPTIONS

BRACHIOPODA

Order PROTREMATA Beecher

Superfamily STROPHOMENACAE Schuchert

Family STROPHOMENIDAE King

Subfamily ORTHOTETINAE Waagen

Genus SCHELLWIENELLA Thomas

SCHELLWIENELLA RUSTICA Stainbrook, n. sp.

Plate 54, figures 40–42

Shell large, convexo-concave, wider than long, subquadrate to subrectangular in outline with long straight hingeline generally less than the greatest width which is near the middle. Dimensions of three specimens are: length 18.4 mm., 17.8 mm. and 21.5 mm. (restored); width 21.7 mm., 22.8 mm., and 32.9 mm.; thickness 8.4 mm., 7.6 mm., and 11.3 mm. The largest example at hand, an incomplete pedicle valve, apparently was at least 48.8 mm. wide.

Pedicle valve generally concave from umbo to front and between lateral margins, flattened centrally. Umbo elevated, broad, sometimes depressed; beak long, pointed, projecting, a little twisted laterally. Cardinal area high, edges sloping rapidly from beak, then gently to angles, divided into three regions; deltidium completely closing delthyrium, moderately convex.

Brachial valve moderately convex, higher near midpoint, surface sloping with nearly equal rapidity to margins, depressed near angles and also along median line in some examples. Umbo broadly convex, elevated and in some projecting posteriorly; beak small; area linear.

Surface of both valves marked by numerous costae, strongly convex, simple, increasing by intercalation several times, about same size near anterior margin except for newly intercalated ones, about three in space of a millimeter at front. Costae slightly rugose where crossed by growth lines. Growth wrinkles strongly expressed near margins of some examples.

The majority of the larger specimens available are preserved as silicified internal molds; only a few smaller ones present the surface in good condition. In general the specimens as usual in the genus are somewhat variable in size, shape, width and convexity. Consequently characters of specific importance are not usually available and the form is apparently similar to species distinguished in the Devonian and the Mississipian. The variability and lack of distinctive features do not favor the members of the genus as good index fossils.

EXPLANATION OF PLATE 53

FIGS. *1–2—Spirifer thomasi* Stainbrook, n. sp. Pedicle and brachial views of the holotype, S.U.I. 8027, collected by A. O. Thomas at Sheffield, Iowa. (p. 378)

3—Spirifer sp. Brachial view, M.A.S. collection, Sheffield, Iowa.

4—Spirifer sp. Pedicle view of a brachial valve, M.A.S., Sheffield, Iowa.

5, 7, 11–13—Liraspirifer tricostatus Stainbrook, n. gen., n. sp. *5*, Pedicle view of a paratype, an internal mold, M.A.S. 1628. *7*, Brachial view of an incomplete paratype, M.A.S. 1644. *11–13*, Pedicle, anterior and lateral view of the holotype, S.U.I. All from Aplington, Iowa. (p. 381)

6—Spirifer sp. Pedicle view of a specimen, M.A.S. Austinville, Iowa.

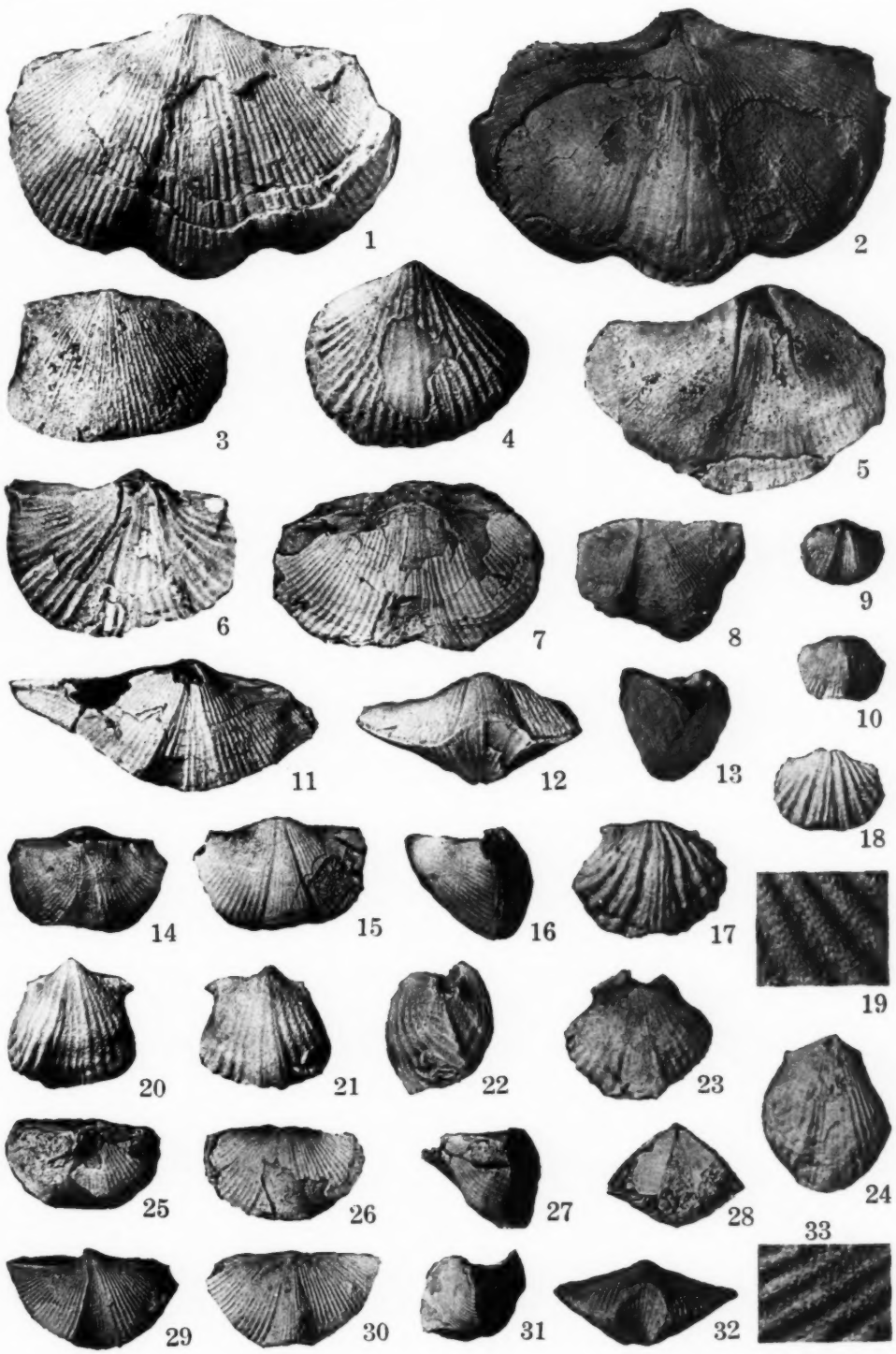
8—Cyrtospirifer sp. External view of an incomplete pedicle valve, M.A.S. Sheffield, Iowa.

9, 10, 14–16—Cyrtospirifer laudoni Stainbrook, n. sp. *9*, *10*, Pedicle and brachial views of a small paratype, M.A.S. 1620, Aplington, Iowa. *14–16*, Pedicle, brachial and lateral views of the holotype, S.U.I. 8028. Sheffield, Iowa. (p. 380)

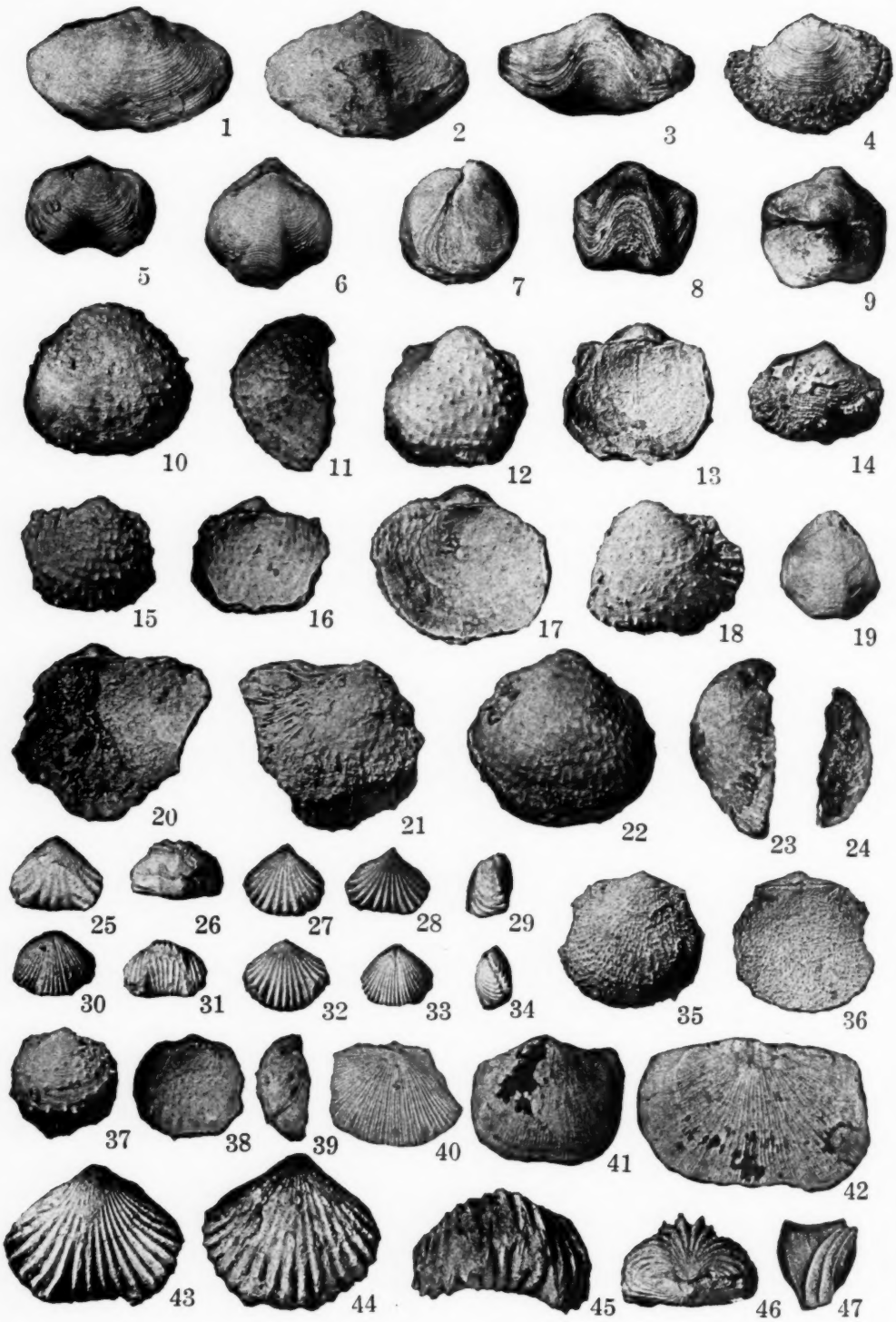
17–24—Arctospirifer constrictus Stainbrook, n. gen., n. sp. *18*, Brachial view of a paratype, M.A.S. 1665. *19*, Enlargement of surface of a paratype, M.A.S. 1665. *20–22*, Pedicle, brachial and lateral views of the holotype, M.A.S. 1647. All from Aplington, Iowa. *23*, Brachial view of a paratype, an internal mold, M.A.S. 1649. *24*, Pedicle view of a gerontic individual, an internal mold, S.U.I. 8030. Both from Sheffield, Iowa. (p. 383)

25–28—Liraspirifer altirostratus Stainbrook, n. sp. *25–27*, Pedicle, brachial and lateral views of the holotype, M.A.S. 1632. *28*, Posterior view of a paratype, M.A.S. 1645. Both from Aplington, Iowa. (p. 381)

29–33—Cyrtospirifer aplingtonensis Stainbrook, n. sp. *29–32*, Pedicle, brachial, lateral and anterior views of the holotype. *33*, Enlarged view, ×7, of its plications. M.A.S. 1622, Aplington, Iowa. (p. 379)



Stainbrook, Aplington formation Brachiopoda



Stainbrook, Aplington formation Brachiopoda

Laudon referred examples from the Aplington to *Orthotetes chemungensis*. *Orthotetes arctostriata*, *Streptostriata* sp., and *Streptorhynchus* sp. The several dozen examples at hand, however, appear to be members of one species of *Schellwienella*.

Schuchertella chemungensis (Conrad) seems never to have been adequately described. Our species does not appear to be one of the varieties described by Hall. It especially differs from *Schuchertella arctostriata* in size, attaining dimensions twice as much. It is near *Schellwienella percha* but apparently differs in that costae are the same size. It is not greatly different from *Schellwienella crenulistriata* Weller, or *Schellwienella planumbona* Weller.

Occurrence.—Aplington dolomite at Aplington and Sheffield, Iowa.

Types.—Holotype M.A.S.[1] 1651; paratypes M.A.S. 1652.

[1] M.A.S. refers to specimens in the Stainbrook collection, which will eventually be deposited at The State University of Iowa. S.U.I. refers to specimens in the collections of The State University of Iowa.

Family PRODUCTIDAE Gray
Subfamily PRODUCTELLINAE Schuchert and Le Vene
Genus PRODUCTELLANA Stainbrook, n. gen.

Shell small, productelloid in shape, moderately concavo-convex, subovate in outline, broadest near midlength, the hingeline less than greatest breadth.

Pedicle valve strongly and regularly arched from beak to front, less strongly transversely, highest at middle; umbo strongly curved, beak small, but little incurved; area low, divided by an apparently open delthyrium.

Brachial valve deepest near middle, surface elevated and concave near angles, more strongly curved upward near front and lateral margins, Cardinal process bifid with median groove, filling opposite delthyrium.

Exterior of pedicle valve marked by concentric irregular lines of growth and by small growth wrinkles near angles. Spine bases few rather than common, circular, may be situated on low, barely perceptible

EXPLANATION OF PLATE 54

FIGS. *1–4, 14—Cleiothyridina vestita* Stainbrook, n. sp. *1–3*, Pedicle, brachial and anterior views of the holotype. M.A.S. 1611. *4, 14*, Brachial views of two paratypes showing well developed spines, M.A.S. 1612. All from Aplington, Iowa. (p. 384)

5–9, 19—Cleiothyridina humerosa Stainbrook, n. sp. *5*, Brachial view of a paratype, M.A.S. 1610. *6–9*, Pedicle, lateral, anterior and posterior views of the holotype, M.A.S. 1609. *19*, Brachial view of a small elongate variety, M.A.S. 1665. All from Aplington, Iowa. (p. 383)

10–13—Leioproductus sheffieldensis Stainbrook, n. sp. *10–11*, Pedicle and lateral views of the holotype, M.A.S. 1655. *12–13*, Pedicle and brachial views of a paratype, M.A.S. 1654. Both from Sheffield, Iowa. (p. 374)

15–18—Leioproductus aplingtonensis Stainbrook, n. sp. *15–16*, Pedicle and brachial views of the holotype, M.A.S. 1657, Sheffield, Iowa. *17*, Brachial view of a paratype, M.A.S. 1658. *18*, Pedicle view of another, M.A.S. 1659. Both from Aplington, Iowa. (p. 375)

20–23—Planoproductus sarmentosa Stainbrook, n. sp. *20–21*, Brachial and pedicle views of the holotype, M.A.S. 1662. *22–23*, Pedicle and lateral views of a paratype, M.A.S. 1663, Both from Aplington, Iowa. (p. 375)

24, 35–36—Strophalosia butlerensis Stainbrook, n. sp. Lateral, pedicle and brachial views of the holotype, M.A.S. 1602, Aplington, Iowa. (p. 375)

25–29—Camarotoechia lauta Stainbrook, n. sp. *25–26*, Pedicle and brachial views of the holotype, M.A.S. 1635. *27*, Brachial view of a paratype. *28–29*, Pedicle and lateral views of another. Both M.A.S. 1640, Aplington, Iowa. (p. 377)

30–34—Camarotoechia nitidula Stainbrook, n. sp. *30–31*, Brachial and anterior views of a paratype. *32*, Pedicle view of another. Both M.A.S. 1642. *33–34*, Brachial and lateral views of the holotype, M.A.S. 1633. All from Sheffield, Iowa. (p. 378)

37–39—Productellana bifaria Stainbrook, n. gen., n. sp. Pedicle, brachial and lateral views of the holotype, M.A.S. 1656, from Hansell, Iowa. (p. 374)

40–42—Schellwienella rustica Stainbrook, n. sp. *40*, Brachial view of the holotype, a small incomplete individual, M.A.S. 1651. *41–42*, Brachial and pedicle views of two paratypes, M.A.S. 1652. All from Aplington, Iowa. (p. 372)

43–47—Camarotoechia unca Stainbrook, n. sp. *43–45*, Pedicle, brachial and anterior views of the holotype, M.A.S. 1640. *46*, Posterior view of a paratype, M.A.S. 1639. *47*, View of a portion of a pedicle valve to show upturning to plications at front, M.A.S. 1643. All from Sheffield, Iowa. (p. 376)

radial corrugations of the surface which do not form plications, no definite arrangement. Spines erect generally, circular in cross section, hollow, short. Brachial valve marked by scattered small spines and dimples, and by concentric wrinkles more prominent near angles.

Productellana is a member of the Productellinae as shown by the nature of the surface of the valves, by their shape, presence of pedicle cardinal area and by the type of spines. It differs from *Productella* in having spines on the brachial valve and from *Avonia* in the presence of a cardinal area on the pedicle valve and lack of definite radial plications near the front of the shell. From *Leioproductus* it differs in having a pedicle cardinal area.

Genotype.—Productellana bifaria Stainbrook, n. sp.

PRODUCTELLANA BIFARIA
Stainbrook, n. sp.
Plate 54, figures 37–39

Shell small, moderately concavo-convex, subovate in outline, the front and lateral margins broadly rounded, the greatest breadth at midlength, hingeline less than greatest width. Measurements of the holotype are: length 15.2 mm., width 16.3 mm.; thickness through convexity of pedicle valve 7.1 mm.

Pedicle valve moderately convex, regularly arched from beak to front and transversely; surface highest at center, curving with equal rapidity to front and lateral margins, concave on each side of beak. Umbo moderately convex, a little projecting; beak broad, short, but little incurved. Area low, edges sloping rapidly from beak at first and then gradually to angles, horizontally striated, delthyrium open. Exterior marked by concentric growth lines and by a few faint discontinuous wrinkles of growth which are more marked near angles. Spine bases small, circular, sometimes situated on faint scarcely perceptible radial upswellings which are not plications. Spines short, hollow, erect.

Brachial valve regularly concave except in areas enclosed by angles. Cardinal process visible and filling opposite delthyrium. Exterior marked by a few irregular discontinuous growth wrinkles and scattered shallow dimples. A few short hollow spines are scattered over surface of valve.

The generic features of this species apparently show it to differ from other related forms of the Mississippian.

Occurrence.—Aplington dolomite, middle beds, 0.5 mi. southeast of Hansell, Iowa.

Types.—Holotype M.A.S. 1656.

Genus LEIOPRODUCTUS Stainbrook 1947

LEIOPRODUCTUS SHEFFIELDENSIS
Stainbrook, n. sp.
Plate 54, figures 10–13

Shell of medium size or below, strongly concavo-convex, subquadrate in outline, a little wider than long, the hingeline generally not equal to greatest breadth. Dimensions of the holotype and a paratype are: length 22.3 mm. and 20.3 mm.; width 24.8 mm. and 21.5 mm.; convexity of pedicle valve 14.2 mm. and 11.3 mm.

Pedicle valve strongly and regularly convex from beak to front, produced posteriorly, strongly arched transversely, flattened centrally with sides descending abruptly to the margins. Central portion depressed or with broad shallow indistinct sulcus which may be nearly obsolete in some examples, angles auriculate. Umbo broadly convex, projecting over hingeline; beak incurved and area linear.

Brachial valve deeply concave, flattened centrally, concave in umbonal region, surface strongly upturned near margins, angles elevated.

Surface of pedicle valve marked by numerous spine bases, small and radially elongate. Those in linear series may appear as plications but are not. The median row of bases may be larger in some examples. Spines generally small, circular and hollow, erect or slanting but not recumbent, larger on angles and along midline as a rule. Growth wrinkles may be developed on angles and sides of umbo, obsolete in middle and front of valve.

Leioproductus sheffieldensis Stainbrook is larger than *Leioproductus plicatus* (Kindle) and has more numerous spines and elongate spine bases.

This is apparently the species identified by Laudon as *Productus costatula* Hall but the absence of areas in the valves and other

features removes it from that genus. It does not resemble the specimens of *Productella costatula* illustrated by Caster.

Occurrence.—Aplington dolomite, upper beds at Sheffield, Iowa.

Types.—Holotype M.A.S. 1655; paratypes M.A.S. 1654.

LEIOPRODUCTUS APLINGTONENSIS
Stainbrook, n. sp.
Plate 54, figures 15–18

Shell of medium size or above, moderately convex, subcircular in outline, with hingeline generally less than the greatest breadth which is at the midlength. Dimensions of the holotype (an incomplete example) and of a paratype are: length 17.5 mm. and 22.5 mm., width 25.9 mm., and 26.6 mm., thickness through convexity 8.9 mm. and 10.2 mm.

Pedicle valve moderately arched from umbo to front, more strongly so over beak, highest near the midpoint, surface curving with equal rapidity to front and lateral margins, more strongly on each side of umbo, concave toward angles. Umbo strong, narrowly convex, a little projecting; beak pointed, short, a little incurved. Area linear, delthyrium occupied by process of opposite valve. Internally are two moderately well developed hinge teeth.

Brachial valve moderately concave, deepest in center, surface elevated toward angles, surface curving upward gently near margins; umbo concave, beak very small, area not developed.

Surface of both valves marked by irregular concentric wrinkles of growth which are more prominent on the cardinal angles. Spine bases numerous on pedicle valve, scattered, elongate. Spines long, slender, circular, hollow, some on angles as much as a centimeter long, all more or less erect or inclined anteriorly but not recumbent. Brachial valve shows only dimples.

This species is near some examples of *Productella* but lack of well developed areas precludes placement in this genus. Assignment to *Leioproductus* seems more appropriate as being in agreement with evolutionary trend in this group of shells.

Leioproductus aplingtonsis differs from *Leioproductus sheffieldensis* in the less produced and thinner shell, and lack of a sulcus in the pedicle valve.

Occurrence.—Aplington formation at Aplington, Iowa.

Types.—Holotype M.A.S. 1657; paratypes M.A.S. 1658, 1659, 1660 and 1661.

Subfamily STROPHALOSIINAE Schuchert
Genus STROPHALOSIA King
STROPHALOSIA BUTLERENSIS
Stainbrook, n. sp.
Plate 54, figures 24, 35–36

Shell of medium size, depressed concave-convex, subcircular in outline, the hingeline apparently shorter than greatest width which is situated at midlength. Measurements of the holotype, a nearly complete specimen, are: length 20.2 mm.; width 21.4 mm. (incomplete); thickness through convexity 6.4 mm.

Pedicle valve highest near middle, the surface sloping thence with nearly equal rapidity to the front and lateral margins, a little concave on each side of the beak; umbonal region a little elevated; beak short, projecting; area low, the margins sloping gradually from the beak, about half as wide as valve, divided by a convex deltidium covering the delthyrium entirely, situated in plane of valve.

Brachial valve concave, shallow, a gently convex ridge extends from beak laterally to each lateral margin; surface concave at angles but elevated a little above remainder of valve; beak small, a little projecting; area low, at right angles to opposite one, divided by a convex chilidium.

Surface of both valves marked by numerous small spine bases, regularly arranged; spines where preserved, short, slender pointed, recumbent on surface of valves.

Occurrence.—Aplington formation at Aplington, Iowa.

Type.—Holotype M.A.S. 1602.

Genus PLANOPRODUCTUS Stainbrook 1947
PLANOPRODUCTUS SARMENTOSA
Stainbrook, n. sp.
Plate 54, figures 20–23

Shells large, moderately convex, produced but little posteriorly, subovate to subcircular in outline, broadest at the mid-

length, the hingeline generally shorter than the width. Measurements of the holotype are: length 25.6 mm., width 27.6 mm. (restored) and thickness through convexity of pedicle valve 10.9 mm.

Pedicle valve highest at midpoint, strongly arched over beak, sloping less rapidly to front, moderately arched transversely with slopes descending rapidly at sides, then concave toward angles; umbo narrowly convex, projecting a little beyond hingeline; beak pointed, projecting and incurved over hingeline. Area apparently linear in several examples; poor preservation makes it impossible to determine in some instances, in other examples the appearance of an area may be due to differential slippage of the valves.

Brachial valve moderately and regularly concave, deepest centrally, surface at angles elevated, without spines.

Surface of pedicle valve marked by numerous spine bases, which are elongate posteriorly, arranged regularly in quincunx. Spines strophalosioid, fine, slender, circular in section, inclined at an angle to surface of valve, generally more or less recumbent, may be about a centimeter long. Faint irregular discontinuous wrinkles of growth and concentric striae common.

The strophalosioid spines and large more depressed shell distinguish this species from other productoids of the formation. The lack of areas and the nature of the spines present only on the pedicle valve apparently place it in this genus as the other related genus, *Bispinoproductus*, has a median series of larger spines.

Occurrence.—Aplington formation, upper beds at Aplington, Iowa.

Type.—Holotype M.A.S. 1662; paratypes 1663.

Order TELOTREMATA Beecher
Superfamily RHYNCHONELLACEA Schuchert
Family RHYNCHONELLIDAE Gray
Genus CAMAROTOECHIA Hall and Clarke
CAMAROTOECHIA UNCA Stainbrook n. sp.
Plate 54, figures 43–47

Shell of medium size, inequally biconvex, subrectangular with broadly rounded anterolateral margins, straight front margins and nearly straight posterolateral margins, wider than long with greatest width anterior to midlength. Dimensions of the holotype and a paratype are: length 22.0 mm. and 16.1 mm. (incomplete); width 26.5 mm and 20.3 mm.; thickness 16.8 mm and 11.4 mm.

Pedicle valve convex only in posterior portion, strongly and regularly arched from beak to front along midline, more so at front; transversely the surface is gently convex centrally, concave anteriorly and strongly curved from umbo to posterior margins. Lateral slopes concave toward anterolateral margins and sharply turned away from brachial valve at edges. Sulcus situated in anterior half of shell, broad, gently concave, bottom projecting to form a large lingual extension which may be slightly recumbent. Umbo low; beak broad, incurved, projecting with apical foramen. Two short diverging dental lamellae are present internally.

Brachial valve the more convex, surface highest anteriorly, sloping thence strongly to the lateral margins and beak and abruptly near the postero-lateral margins. Slopes strongly arched from back to front. Umbo broad, low; beak short, concealed. Fold in anterior half of valve, broad, shortened centrally by opposite lingual extension. Internally there is a thin median septum.

Surface wholly plicate; plications large, strong, simple, narrow, acutely angular at summits with high outer and low inner slopes; numbering six on fold and five in sulcus, but may be four or five in smaller examples; about 10 on each slope, those near angles being small. Ends of plications in well preserved specimens curve upward strongly at front on the fold and on the anterolateral margins of the pedicle valve in characteristic fashion. Because of silification surface markings are not preserved. One or two have faint indications of radial striae.

In appearance this species has considerable resemblance to examples of *Tetracamera* but lacks the internal characters of that genus. It seems to be unlike any other Mississippian form.

This species was identified by Laudon as *Camarotoechia sappho* and does resemble it to some extent. *Camarotoechia sappho* is, however, highly variable and thus would

appear like several forms. It is, therefore, difficult to distinguish them without specimens of the latter at hand.

Camarotoechia unca differs from *Camarotoechia sappho* in form, in having more acutely angular plications which are not split at the anterior commissure as mentioned by Caster, and a more rounded fold. The abrupt upward curvature of the plications at the front of the fold and the posterolateral margins of the pedicle valve is a feature not seen in *Camarotoechia sappho*. These features seem sufficient to delimit *Camarotoechia unca* from that form.

Occurrence.—Aplington dolomite at Sheffield, Iowa.

Types.—Holotype M.A.S. 1640; paratypes M.A.S. 1638, 1639, 1643.

CAMAROTOECHIA LAUTA Stainbrook, n. sp.
Plate 54, figures 25–29

Shell small, subequally biconvex, subtriangular in outline with straight front margin, broadly rounded lateral margins and posterolateral margins meeting in an acute angle at the beak, a little wider than long, broadest anterior to the midlength, anterior commissure linguate and dentate. Measurements of the holotype and two paratypes are: length 10.5 mm., 10.3 mm. and 11.5 mm.; width 12.2 mm., 11.2 mm. and 13.5 mm.; thickness 6.6 mm., 6.6 mm. and 8.4 mm.

Pedicle valve depressed convex, moderately arched along the midline, more strongly so anteriorly, gently arched transversely at the midlength, surface highest at umbo, a little concave toward anterolateral margins, incurved on either side of umbo; sulcus confined to anterior half of valve, broad, shallow at front, not well defined at sides, continued at front to form a short quadrate lingual extension; umbo low, narrowly convex, projecting a little posteriorly; beak small, acutely pointed, gently curved, bearing a small apical foramen; delthyrium partially closed by deltidial plates, bordered by small area. Two short dental lamellae are present internally.

Brachial valve depressed convex, gently arching from umbo to front, more strongly to beak, gently arched transversely; surface highest at the midpoint, sloping gently for some distance, then rapidly to the lateral and posterolateral margins; fold apparent only on anterior half of valve, broad, flat, elevated but little above remainder of valve; umbo low, broad with gentle median depression; beak small; slopes gently arched except at front where edges are strongly curved toward opposite valve. Internally a thin median septum extends forward to the midpoint.

Entire surface of valves plicate; plications strong, simple, angular at summits, numbering four on the fold, three in the sulcus, and about five strong ones on each slope with two or three weak ones near angles; total number averaging about 18–26. A few examples may show five on fold but these are a distinct minority.

Camarotoechia lauta was identified by Laudon (1931, p. 254) as *Camarotoechia contracta* but it differs from that form in a number of details. Caster has recently illustrated examples from the late Upper Devonian of New York and Pennsylvania and his identifications are taken to give the latest authentic characteristics of the species. *Camarotoechia lauta* is much smaller, about half as large on the average, and differs in shape, in form of fold and sulcus, and possibly in number of plications, generally averaging slightly more. Although it has four plications on the fold, *Camarotoechia lauta* does not appear to be even a variety of that somewhat variable species, so variable as now recognized, that some doubt might be entertained as to its value as an index fossil.

Our species resembles *Camarotoechia elegantula* Rowley of the Burlington limestone more than it does *Camarotoechia contracta*. It averages a little larger, is a little less transverse and has more plications on each slope. It is near *Camarotoechia chouteauensis* Weller but is generally thinner and averages fewer plications in the sulcus.

Camarotoechia lauta is also similar to *Camarotoechia sobrina* Stainbrook but dffers in having more plications which do not turn strongly upward at the front of the brachial valve and on the anterolateral margins of the pedicle valve.

Occurrence.—Aplington formation, Aplington and Sheffield, Iowa.

Types.—Holotype M.A.S. 1635; paratypes M.A.S. 1641 and 1636.

CAMAROTOECHIA NITIDULA
Stainbrook, n. sp.
Plate 54, figure 30–34

Shell small, subequally biconvex, subtriangular in outline with nearly straight front margin and broadly curved lateral margins, the posterolateral margins forming an obtuse angle, a little wider than long, the greatest width anterior to the midlength, anterior commissure sinuous and dentate. Dimensions of the holotype and two paratypes are: length 8.9 mm. (incomplete), 10.1 mm. and 11.1 mm.; width 10.7 mm., 12.8 mm. and 12.4 mm.; thickness 5.5 mm., 7.1 mm. and 7.4 mm.

Pedicle valve moderately and regularly arched along the midline from beak but more rapidly at front; surface highest on umbo, sloping but little thence to anterolateral margins, gently to posterolateral margins, gently arched transversely; sulcus beginning on umbo, shallow, broad at front, nearly flat at bottom which is continued at front as a short subquadrate lingual extension, sides of sulcus merging with lateral slopes; umbo broad, low; beak short, curved, generally missing in specimens at hand. Internally two short dental lamellae extend forward a short way, diverging somewhat.

Brachial valve strongly and regularly arched from beak to midpoint, gently thence to front; surface highest at midpoint, sloping with moderate rapidity to sides, incurved on sides of umbo. Fold originating on umbo, broadening to front, not much elevated there, generally convex. Umbo low, may bear short linear depression; beak small, broad. A thin median septum extends forward internally nearly to the midpoint.

Surface plicate; plications may be simple or may increase by division on slopes and fold, generally rather small, angular at the summit, averaging about seven on the fold and six in the sulcus, 10 to 12 (sometimes nine) on each slope.

Most of the specimens are preserved as silicified internal molds. Some external details are therefore obscured.

Distinguishing features are the small size and large number of plications which may increase by division and the generally rounded fold. It differs from *Camarotoechia lauta* with which it occurs in that it averages slightly larger, and has more numerous and smaller plications on the fold which may increase by division in some instances, and a rounded fold which has seven instead of four plications.

This form was identified by Laudon as *Camarotoechia contracta* but it is considerably smaller, differently shaped, has more plications on fold, more numerous smaller plications on slopes and different fold and sulcus.

It resembles *Camarotoechia mutata* to some extent but is slightly larger and has more numerous plications.

Occurrence.—Aplington dolomite, Sheffield Iowa.

Types.—Holotype M.A.S. 1633; paratypes M.A.S. 1634, 1642.

Superfamily SPIRIFERACEA Waagen
Family SPIRIFERIDAE King
Genus SPIRIFER Sowerby
SPIRIFER THOMASI Stainbrook, n. sp.
Plate 53, figures 1–2

Shell large, spiriferoid, dorsoventrally compressed, semielliptical in outline, trilobate at front margin, considerably broader than long, the angles slightly extended. Holotype measures 38.4 mm. in length, 56.2 mm. in width (slightly incomplete), and 19.5 mm. in thickness (less than actual).

Pedicle valve moderately convex, arching with even curvature from beak to front, gently arched transversely, depressed toward angles. Sulcus beginning at beak, shallow, concave at bottom posteriorly but gently and broadly convex anteriorly, limited at sides by an interplication furrow which is somewhat stronger than those on slopes, extended at front into a short rounded lingual projection whose lateral borders are strongly indented. Slopes gently arched from borders of sulcus to sides and from the beak to the front. Umbo broadly convex, projecting beyond hingeline. Beak broad and but little incurved, flat. Cardinal area slightly curved, posterior borders descending rapidly from the beak for a short way and then curving to the hinge extremities; delthyrium about as broad as high. The internal mold of a paratype shows the imprint of a strong transverse delthyrial plate in the apical portion of the delthy-

rium. Delthyrial supporting plates strong, extending a short way anteriorly. Muscle scar flabellate, extending forward about half the length.

Brachial valve about as convex as the pedicle, arching with moderate rapidity to the front, more strongly curved posteriorly, broadly arched transversely. Fold depressed convex, extending from beak to front, a little elevated over slopes, bordered at sides by larger furrows deeper than those between plications. Slopes moderately arched from fold to sides, depressed toward angles. Umbo broad, low, projecting but little posteriorly; beak small, a little incurved, area low. Internally there is a low median ridge extending more than half way toward the front.

Slopes of both valves marked by numerous radiating simple plications, rounded, wider than the furrows between them, numbering about 31 to a slope; those of fold and sulcus increasing in number toward front, the increase occurring on either side of the median line, about 12 in sulcus of which the one on each border is considerably larger. Finer markings not preserved on specimens at hand with the exception of a few striae of growth.

The shape and trilobate front margin distinguish this form from any other known to us.

Occurrence.—Aplington formation near middle, in region of Sheffield, Iowa.

Types.—Holotype S.U.I., collected by A. O. Thomas; paratypes M.A.S. and the Iowa Geological Survey collections.

Genus CYRTOSPIRIFER Nalivikin

CYRTOSPIRIFER APLINGTONENSIS
Stainbrook, n. sp.
Plate 53, figures 29–33

Shell medium to large, wider than long, inequally biconvex, transversely subelliptical with short front margin and anterolateral margins curving gradually toward the front, angles a little extended, anterior commissure strongly sinuate centrally. Dimensions of the holotype, a medium sized individual, are: length 13.1 mm.; width 25.2 mm.; thickness 11.6 mm. A pedicle valve, an internal mold, measures 22.1 mm. in length, 33.6 mm. in width (partially restored).

Pedicle valve moderately convex, strongly and regularly arched along midline from beak to front, highest in the umbonal region, strongly arched transversely. Slopes gently curved from back to front. Sulcus beginning at beak, enlarging gradually to the front, gently rounded at the bottom, the sides sloping rapidly, continued as a moderately long rounded lingual extension. Umbo long, narrow; beak long, pointed, generally twisted laterally. Cardinal area high, flat for the most part, strongly curved toward the beak, anteriorly inclined near hingeline; portions on each side of delthyrium divided into regions of which the inner is vertically striated, the outer horizontally striated and pustulose as on slopes. Margins of area sloping rapidly from the beak a short way, then with moderate rapidity to the angles, sometimes projecting as shelf-like extensions near angles. Delthyrium high, quite narrow and with short transverse delthyrial plate which is concave anteriorly. Internally the delthyrial supporting plates extend anteriorly more than halfway to the midpoint.

Brachial valve less convex than other, gently and regularly arched from beak to front along midline, highest at the midpoint. Fold beginning at beak, widening gradually to front, broadly convex, moderately elevated above remainder of the valve, truncated at front by opposite sulcus. Slopes gently arched from hingeline forward, more strongly so near fold, sloping gradually from fold laterally, a little concave near angles. Area low, divided by a broad low notothyrium.

Slopes, fold and sulcus entirely plicate. Plications small, narrow, convex at summits, separated by deep narrow grooves, simple and numbering about 22 on each slope in the holotype; about 14 on fold, increasing by division which takes place in median portion of the fold or sulcus. A large pedicle valve has nearly 40 on a slope and another has 30. Surface of plications covered with granulose pustulae which tend to be arranged in radiating lines. There is a suggestion that the pustulae are spine bases as few very fine microscopic spinulae are visible on the surface where a little matrix remains.

Cyrtospirifer aplingtonensis is among those identified by Laudon as *Spirifer dis-*

junctus but it differs from that variable species in shape, form of area and external markings.

Cyrtospirifer disjunctus as commonly identified in the New York Devonian is a highly variable form. Variations might be of value in stratigraphy if they were correlated with occurrence in distinct horizons. But as now constituted, *Spirifer disjunctus* has little correlative value. The *Spirifer disjunctus* gens is said by Caster to occur in the basal Mississippian of the Allegheny region.

Cyrtospirifer aplingtonensis differs from *Cyrtospirifer whitneyi* (Hall) from the Lime Creek of the Iowa Devonian in general appearance, in having a less curved area, less convex fold, shallower sulcus, narrower and more numerous plications, and in the nature of the fine external markings. The species resembles *Cyrtospirifer animasensis* (Girty) in general form but its area is not as high and is more curved especially near the beak, and the delthyrial plate is not as long. The finer markings of *Cyrtospirifer animasensis* are more ridgelike and less granulose than in our form and shorter.

Occurrence.—Aplington formation, upper beds near Aplington and Sheffield, Iowa.

Types.—Holotype M.A.S. 1622; paratypes M.A.S. 1623, 1646.

CYRTOSPIRIFER LAUDONI
Stainbrook, n. sp.
Plate 53, figures 9–10, 14–16

Shell of medium size or above, wider than long, strongly and very inequally biconvex, transversely subquadrate in outline with slightly extended angles and anterior commissure gently sinuate centrally. The holotype measures 16.7 mm. in length, 22.9 mm. in width and 6.7 mm. in thickness.

Pedicle valve strongly convex, gently and regularly arched along the midline from beak to front, subpyramidal, highest at the beak; slopes nearly flat from beak to lateral margins. Sulcus originating at the beak, shallow, gently concave at bottom, gradually enlarging to front, slightly projecting there into a short lingual extension. Umbo high, narrow, a little curved. Beak long, sharp, laterally twisted slightly. Cardinal area high, flat for the greater part, gently curved toward apex, about at right angles to plane of valve. Delthyrium high, narrow with short transverse delthyrial plate.

Brachial valve much less convex than the pedicle, moderately and regularly arched from beak to front, highest at midpoint. Fold initiated at the beak, widening gradually to front, low, gently convex and but little elevated above remainder of the valve. Slopes gently convex from back to front, slightly concave toward angles. Umbo broad, low; beak short.

Slopes, sulcus and fold completely plicate. Plications small, narrow, convex at top, separated by narrower furrows, simple and numbering about 20 on each slope; about 15 on fold and in sulcus increase by division on each side of the midline. Surface of plications where preserved granulose.

Cyrtospirifer laudoni is smaller than *Cyrtospirifer aplingtonensis* with which it occurs, is much narrower, and has slightly or non-extended angles. The cardinal area is higher and forms almost an equilateral triangle. The quadrate outline is distinctive as in the other the anterolateral margins curve gradually from the angles to the front.

The high, narrow and less curved area, the shape and smaller plications distinguish this from *Cyrtospirifer whitneyi* (Hall).

Occurrence.—Aplington formation near Sheffield and Aplington, Iowa.

Types.—Holotype S.U.I. 8028, collected by L. R. Laudon; paratype M.A.S. 1620.

LIRASPIRIFER Stainbrook, n. gen.

Shell medium to large, spiriferoid in shape, wider than long with short or extended angles, hingeline may equal or be less than greatest width, anterolateral margins long, front margin short.

Pedicle valve more convex than the brachial, highest in the umbonal region, surface sloping strongly thence to the front and lateral margins, a little concave toward the angles, gently arched along the midline. Sulcus originating at the beak, shallow, wide, gently convex at bottom, a little extended at front. Umbo high pyramidal. Beak pointed, little or not at all incurved, may be twisted laterally. Cardinal area high, flat or slightly curved, about at right angles to the plane of the valve, vertically striated in area on each side of delthyrium, edges sloping in straight lines to extremities. Delthyrium high, narrow. Internally the delthyrial supporting plates extend forward a short way along floor of the valve. A

short, anteriorly concave, transverse delthyrial plate appears in apical portion of the delthyrium, sunken below the area.

Brachial valve gently convex, transversely arched centrally, a little depressed toward angles. Fold originating at the beak, low, broadly convex, wide at front, elevated a little above the remainder of the valve, truncated by opposite sulcus. Area low, divided by a broad low notothyrium, situated in plane of valve. Slopes gently arched from back to front, sloping gently from fold laterally.

Surface of fold, sulcus and slopes of both valves plicate. Plications numerous, low, narrow, gently convex or flattened, separated by narrower furrows, decreasing in size gradually to the angles, only those nearest fold reach beaks; those in sulcus and fold increase by division, those on slopes are simple. Each plication is marked by two longitudinal grooves which give it the appearance of having three costae making each plication.

In form and appearance *Liraspirifer* is similar to *Cyrtospirifer* but area is generally higher and less curved. The tripartite nature of the plications is a distinct feature not seen in any member of *Cyrtospirifer* known to the writer. *Liraspirifer* also does not carry minute surface papillae as seen in *Cyrtospirifer whitneyi* (Hall).

Liraspirifer differs from *Spirifer* in the tricostate nature of the plications.

Genotype. Liraspirifer tricostatus Stainbrook, new species. Another member of the genus is *Liraspirifer altirostratus* Stainbrook, n. sp.

LIRASPIRIFER TRICOSTATUS
Stainbrook, n. sp.
Plate 53, figures 5, 7, 11–13

Shell medium to large in size, inequally biconvex, much longer than wide with greatest width along hingeline, semielliptical in outline with angles extended, the anterior commissure gently sinuous. Dimensions of the holotype are: length 15.5 mm., width 49.6 mm. thickness 16.6 mm. Larger incomplete examples are at hand.

Pedicle valve the more convex, highest at the beak, the surface sloping strongly thence to the front and lateral margins. Slopes gently curved from hingeline to the front, nearly flat from middle to anterolateral margins, a little concave anterior to the hingeline, concave toward angles. Sulcus shallow, gently concave at bottom, bordered at sides by slightly larger plications. Cardinal area high, flat, the margins sloping gently from beak at first, then straightening out for a short distance so that shelf-like posterior projections are developed. Delthyrium high, open; a short transverse plate in apex below level of area. Delthyrial supporting plates strong, apparently short.

Brachial valve gently arched along the midline from beak to front, more strongly so posteriorly, moderately arched transversely in central part, depressed toward angles. Fold low, broad at front, gently convex, elevated above remainder of valve. Umbo low, broadly convex; beak short, a little incurved, area low.

Plications numerous, simple on slopes, dividing on fold and sulcus, numbering about 39 on each slope and about 12 in fold and sulcus. On fold at beak is one plication which divides into three which bifurcate several times toward front. Plications narrow, low, gently convex to nearly flat, and divided into three costae by two narrow grooves extending full length of the plication. Interplicational furrows nearly as wide as plications, shallow, marked by concentric striae of growth.

Liraspirifer tricostatus apparently is unlike any other spiriferoid in the Mississippian of the upper Mississippi valley. Distinctive features are the shortness of the shell, extended cardinal angles, high and nearly flat cardinal area and tricostate plications.

Although this form has been identified as *Spirifer disjunctus* the nature of the plications indicates that it is not closely related to that form or to any variety of it.

Occurrence.—Aplington formation, basal beds at Aplington, Iowa.

Types.—Holotype M.A.S. 1624; paratypes M.A.S. 1625, 1644.

LIRASPIRIFER ALTIROSTRATUS
Stainbrook, n. sp.
Plate 53, figures 25–28

Shell above medium size, very inequally biconvex, wider than long with greatest width along the hingeline, transversely semielliptical with angles slightly extended, anterolateral margins broadly rounded and

nearly at right angles to the hingeline, front margin short, the anterior commissure sinuous. The holotype measures 12.8 mm. in length, 22.4 mm. in width (a little incomplete) and 15.5 in thickness.

Pedicle valve much the more convex, subpyramidal, highest at the beak, the surface sloping strongly thence to the front and lateral margins. Sulcus originating at the beak, broad at front, shallowly concave, projecting anteriorly. Umbo small, pyramidal; beak sharp, may be a little twisted. Cardinal area high, nearly flat or very slightly curved, at right angles to the plane of the valve or possibly a little inclined toward the front, divided on each side of the delthyrium into two areas, of which the inner is vertically striated. Lateral edges of the area forming nearly straight lines from the beak to the angles. Delthyrium high, narrow, showing a short transverse delthyrial plate below area in apical portion. Delthyrial supporting plates moderately strong, extending some distance forward along the floor of the valve.

Brachial valve gently convex, moderately and regularly arched from beak to front, highest at the middle, gently concave toward angles. Fold low, broadly convex, slightly elevated above remainder of valve; area low, at right angles to that opposite, divided by a low, broad notothyrium.

Plications numerous, narrow, simple on slopes, low, gently convex, marked by two longitudinal grooves which gives them a tricostate appearance in well preserved individuals, multiplying by division in fold and sulcus, numbering about 17–20 on each slope. One plication at beak divides into two which extend thence to the front, increasing by division which takes place only in middle of fold and sulcus.

This species was identified as a variety of *Spirifer disjunctus* by Laudon but the nature of the plications apparently shows that it is not a member of that clan.

It is smaller than *Liraspirifer tricostatus*, proportionately much narrower, has angles but little extended and a proportionately higher cardinal area.

Occurrence.—Aplington formation, basal beds at Aplington, Iowa.

Types.—Holotype M.A.S. 1632; paratypes M.A.S. 1630, 1645.

ARCTOSPIRIFER Stainbrook, n. gen.

Shells of medium size, subequally biconvex, spiriferoid but very narrowly so in shape, subovate in outline, wider than long, the greatest width generally anterior; hingeline straight, nearly equal to breadth, angles extended as shell is considerably contracted immediately anterior; anterior commissure sinuous.

Pedicle valve the more convex, highest in umbonal region, strongly arched from beak to front and transversely with sides near margins nearly at right angles to plane of the valve. Sulcus shallow, extending from beak to front, forming a short lingual extension. Slopes strongly concave laterally in front of angles. Umbo narrow; beak projecting and incurved. Cardinal area moderately high, curved; delthyrium open, high narrow with a short delthyrial plate.

Brachial valve strongly arched over umbo, less strongly to front, moderately arched transversely. Fold initiated at beak, increasing in width and height to front, convex, elevated above remainder of valve.

Slopes, fold and sulcus strongly plicate. Plications large, convex, separated by narrow furrows; generally simple on slopes but may bifurcate, especially in large examples, numbering six to nine generally; about 10 on fold and in sulcus. On fold one plication is seen at beak which bifurcates and each then bifurcates in turn. Plications in fold and sulcus not as large as those on slopes.

Exterior on well preserved examples, except cardinal area, covered by fine crowded pustulae. Where these are removed by wear and on beaks the surface is marked by numerous short ridgelets more or less radially arranged; in some instances they may turn from the furrows toward the plications.

Genotype. Arctospirifer constrictus Stainbrook, n. sp.

The genus resembles *Brachythyris* somewhat in general appearance but differs in that the angles are extended with the sides contracted immediately anterior, the plications on the slopes may bifurcate and the surface markings differ markedly.

From *Cyrtospirifer* it differs in the shape, shorter hingeline, proportionately larger and fewer plications which may bifurcate on

slopes and different method of increase of plications on fold.

ARCTOSPIRIFER CONSTRICTUS
Stainbrook, n. sp.
Plate 53, figures 18–24

Shell small to medium in size, subequally biconvex, subovate in outline, wider than long, greatest width anterior to midlength, narrow in front of the straight hingeline, angles extended but generally not attaining or exceeding width, anterior commissure sinuous. Dimensions of the holotype are: length 16.6 mm.; width 18.6 mm.; thickness 14.1 mm.; hingeline 16.2 mm. (restored). A brachial valve is 15.7 mm. long and 21.2 mm. wide. A large internal mold is 16.5 mm. long, 20.7, mm. wide and 13.2 mm. thick.

Pedicle valve strongly arched along midline from beak to front. Strongly arched transversely, flattened a little anteriorly and with sides sloping abruptly, highest in the umbonal region; surface curving regularly along borders of sulcus to front, and abruptly thence to lateral margins, incurved beneath beak. Sulcus beginning at apex, widening toward front, shallow, gently concave at bottom in mature examples. Umbo high, narrow, arching; beak long, pointed, projecting, incurved. Area high, curved, more strongly so beneath beak, inclined a little anteriorly near hingeline, vertically and horizontally striated, nearly the same height beyond beak to extremities, the margins making shelf-like extensions on slopes. Delthyrium high, narrow with a short apical transverse plate. Internally the delthyrial supporting plates extend forward a short way along floor of valve.

Brachial valve strongly arched over the umbo but less so to the front along midline, highest in front of the midpoint, strongly and regularly arched transversely, more so at front. Fold originating at beak, broadly convex, elevated above remainder of valve but not distinctly set off from it. Slopes arched with moderate rapidity from hingeline to front, constricted in front of angles. Umbo broad, low; beak small. Area low, in plane of valve.

Slopes, fold and sulcus strongly plicate. Plications strongest on slopes, averaging about eight on each, strongly convex, with deep furrow between, may be simple or bifurcating, especially in mature specimens; number about ten on fold and in sulcus, increasing by division, each new plication usually dividing. In well preserved examples the surface, except area, is covered by numerous nodose pustulae which are generally situated on radial ridges, especially visible where pustulae are worn. Ridgelets may diverge from furrows toward summits of plications.

The shape, short hingeline, constriction of valves in front of it, nature of area, bifurcation of plications are distinctive of the species. No similar species is known to the writer.

Occurrence.—Aplington formation, upper portion at Aplington and Sheffield, Iowa.

Types.—Holotype M.A.S. 1647; paratypes M.A.S. 1648, 1649, 1650.

Family ATHYRIDAE
Genus CLEIOTHYRIDINA Buckman
CLEIOTHYRIDINA HUMEROSA
Stainbrook, n. sp.
Plate 54, figures 5–9, 19

Athyris angelica LAUDON, 1931, Iowa Acad. of Sci., vol. 37, p. 254.

Shell below medium size, strongly biconvex, gibbous, broadest near middle or anterior, subovate in outline with lateral margins broadly rounded, anterior margin short and straight, posterolateral margins long, hingeline short, commissure uniplicate, lateral commissures strongly sinuous. Measurements of the holotype and three paratypes are: length 17.6 mm., 15.2 mm., 17.4 mm., and 15.2 mm.; width 17.0 mm., 18.3 mm., 18.2 mm., and 20.4 mm.; thickness 17.9 mm., 13.7 mm., 14.2 mm., and 14.4 mm. Two specimens of what may be a smaller variant measure 13.8 mm. and 12.3 mm. in length; 12.1 mm. and 11.7 mm. in width; 9.7 mm. and 8.4 mm. in thickness.

Pedicle valve strongly convex, arched in a semicircle along midline, a little more strongly posteriorly, strongly arched transversely and nearly quadrate; surface concave on either side of beak. Sulcus originating well up on umbo, widening, and deepening gradually to front, gently concave at bottom, bordered at sides by moderately strong ridges, protruding at front in a long lingual extension. Lateral slopes nearly flat,

a little concave toward ridges bordering sulcus, dropping thence abruptly at nearly right angles to lateral margins. Umbo strongly convex, a little compressed laterally. Beak small, pointed, projecting beyond hingeline, a little incurved, with subcircular apical foramen.

Brachial valve strongly convex, strongly arched along midline from umbo to beak, gently thence to front, moderately arched transversely in posterior half. Fold strong, extending well up on umbo, broadly rounded, flattened, bordered laterally by deep sulci which are narrow at bottom and projecting at front into angular extensions. Slopes strongly arched from sulci to posterolateral margins. Umbo broadly convex; beak small, a little pointed.

Surface of both valves where well preserved marked by numerous more or less regularly spaced concentric growth lamellae which support flat slender spines a millimeter long and rounded distally. Spines crowded at front in old gibbous individuals and may appear as a close-set series of fringes giving the shell a bearded appearance.

Cleiothyridina humerosa appears to be close to *Cleiothyridina prouti* Shumard but differs in that the length is more nearly equal to or approaches the width, the fold well defined, and the lateral slopes distinctly set off at the front by sulci. Surface likewise when denuded of spines does not appear reticulate to any large extent.

The presence of flat spines shows that this species cannot be referred to *Athyris angelica* Hall. It also appears to differ in shape from that somewhat variable species.

Occurrence.—Aplington dolomite at Aplington and Sheffield, Iowa.

Types.—Holotype M.A.S. 1609; paratypes M.A.S. 1610 and 1665.

CLEIOTHYRIDINA VESTITA
Stainbrook, n. sp.
Plate 54, figures 1–4, 14

Shell of medium size, subequally biconvex, elliptical in outline with posterolateral margins less rounded than the anterolateral margins, broadest near the midlength. Dimensions of the holotype and of two paratypes are: length 15.4 mm., 17.8 mm. and 19.0 mm.; width 20.3 mm., 29.0 mm. and 26.9 mm.; thickness 9.6 mm., 14.7 mm. and 19.2 mm. Slightly larger dimensions may be attained.

Pedicle valve moderately convex, highest in umbonal region, the surface sloping thence in nearly straight lines to the anterolateral margins, regularly and strongly convex from beak to front along midline. Lateral slopes somewhat flattened toward outer margins. Sulcus distinct in front half of valve, originating on umbo, broadly rounded at bottom, anterior projecting as a rounded lingual extension. Umbo broad, low, smooth, projecting slightly, curved, but little posteriorly; beak small, short, projecting a little, bearing a large rounded apical foramen.

Brachial valve regularly and moderately curved along midline, highest near center, the surface gently sloping from the fold to the sides, depressed a little on each side of beak. Fold originating near midlength, broadly convex, highest at front and bordered there on each side by broad shallow sulci, truncated at front by opposite lingual extension. Umbo broad, low, smooth; beak small, projecting a little, incurved beneath opposite foramen.

Exterior of both valves marked by numerous, generally regularly spaced lamellose growth lines, each lamella bears on edge a single row of elongate slender flat spines about 2.4 mm. long. Toward the front of many specimens the spines may be numerous and crowded so as to give a bearded appearance to the shell.

Cleiothyridina vestita differs from *Cleiothyridina humerosa* in the larger, more transverse and proportionately less thin shell. The spines are longer and are more often preserved.

Occurrence.—Aplington formation, especially abundant in basal beds but present in upper zones as well at Aplington, Austinville and Sheffield, Iowa.

Types.—Holotype M.A.S. 1011; paratypes M.A.S. 1012.

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JOURNAL OF PALEONTOLOGY, VOL. 24, NO. 3, PP. 386–389, 2 TEXT FIGS., MAY 1950

PALEONTOLOGICAL NOTES

A PLATYSOMID FROM THE DOUBLE MOUNTAIN GROUP OF TEXAS

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Platysomids from North America have been known since the first description by Newberry and Worthen (1870) of Pennsylvanian specimens from Mazon Creek, Illinois. They established the species *Platysomus circularis* and *P. orbicularis*. In 1891 Cope added *P. lacovianus* to the same fauna and *P. palmaris* from the Permian of the "southern Indian Territory." Since these earliest mentions of deep-bodied paleoniscoids, other specimens have been reported from the Triassic of Alberta, the Wichita and Clear Fork of Texas, and the Enid of Oklahoma.

The European platysomids are more numerous and a considerable number of species have been described since *P. gibbosus* was established as the genotype by Agassiz (1833–35). Stensio (1921) hesitantly referred certain fragmentary specimens from

FIG. 1—*Platysomus* sp. Lateral view of right side of specimen from the Blaine formation of King County, Texas. ×2.5. T.M.M. no. 953-1.

the Eotriassic of Spitzbergen to the genus *Platysomus* and expressed doubt that *P. canadensis* Lambe (1914) from the Triassic of Alberta was correctly identified as *Platysomus*. Later Stensio (1932) described the genus *Bobosatrania* and referred to it the material previously described (1921) as *Platysomus*.

The geologic range of *Platysomus* in North America extends from the Pennsylvanian to the Permian with, at the least, a closely related form in the Lower Triassic. Recently, Mr. Glen L. Evans, Assistant Director of the Texas Memorial Museum, Austin, has graciously lent the writer for study four specimens of *Platysomus* which he collected in 1942 from King County, Texas. These are Texas Memorial Museum specimens No. 953–1, 953-2, 953-3, and 953-4. These specimens are interesting for several reasons in spite of the fact that they are so poorly preserved that they can add nothing to the morphology of the genus.

To Mr. Evans' and the author's knowledge, they are the first vertebrate fossils to be recovered from the Double Mountain group of the Texas Permian. It is impossible at this time to determine an exact stratigraphic position for the locality, but Mr. Evans has estimated it to be within the lower 250 feet of the Blaine formation. The locality may be reached by turning north from the Knox City-Guthrie road about three-quarters of a mile south of Buzzard's Peak on a dim trail which extends about a quarter of a mile to a low saddle. The specimens occur in mudstone concretions which are plentiful at the locality.

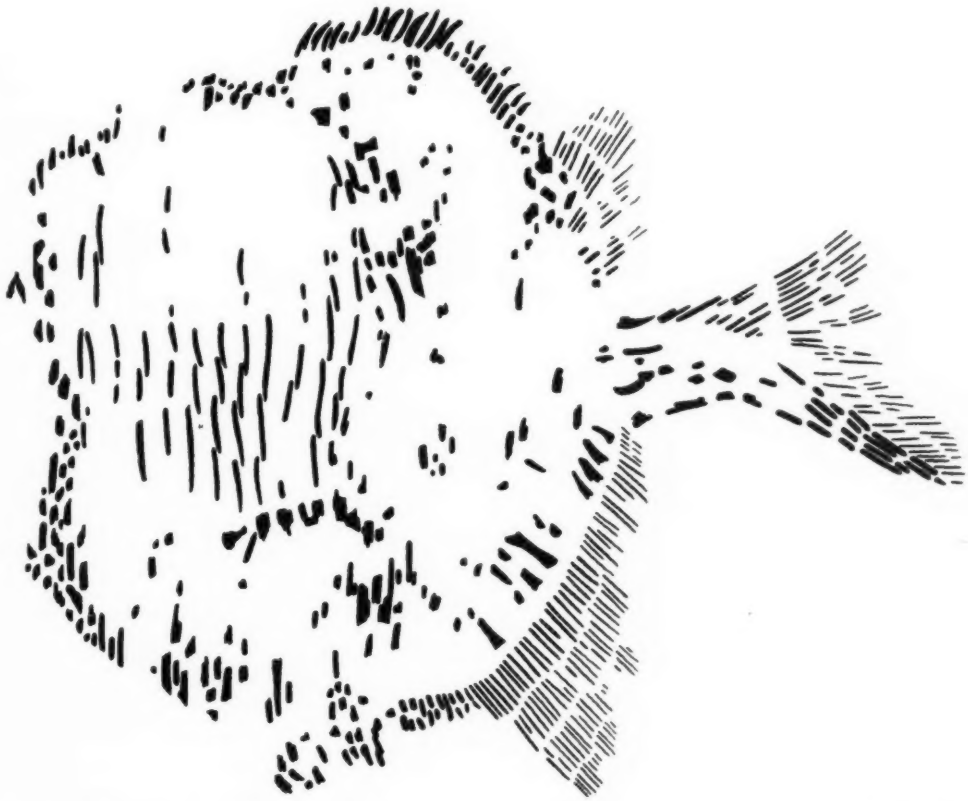

FIG. 2—*Platysomus* sp. Lateral view of right side of specimen from the Blaine formation of King County, Texas. ×3. T.M.M. no. 953-2.

The changes in the environment of the North American platysomids now present an interesting sequence. The Pennsylvanian species were definitely fresh-water forms living in or close to coal-swamp conditions; the Wichita-Clear Fork species were also fresh-water inhabitants but the coal-swamp environment had changed to one of red beds. The climate had become considerably less moist. In the Blaine formation the *Platysomus* specimens were collected from a channel fill which had massive beds of gypsum above and below it. The conditions seem to indicate that the channel was on the edge of a dessicating basin which was probably filled with brackish water, according to information supplied by Mr. Evans. The *Platysomus* (?) of the Lower Triassic of Alberta was found in marine beds associated with "a species of Lingula, various species of pelecypods and ammonites" (Kindle, in Lambe, 1916). The change from a fresh-water to a marine habitat was thus complete.

An increase in size is correlatable with the change in habitat. The Pennsylvanian forms are small, 3–4 cm. in length; the Blaine form somewhat larger, 6–7 cm.; and with the adoption of a marine habitat the size increased enormously to 3 feet 8 inches for *P. canadensis*.

The above assumes, and the author believes rightfully so, that there is a phylogenetic sequence between the end forms previously mentioned from North America and that the change of the platysomids from a fresh-water habitat to a marine habitat can be demonstrated to parallel very closely the changing climatic conditions in the central part of North America between the Pennsylvanian and the Lower Triassic.

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THE AGE OF THE GUADUAS FORMATION IN COLOMBIA; A CORRECTION.[1]

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In a previous paper (1948) I have discussed the larger Foraminifera from a Maestrichtian limestone which I included in the Guaduas formation in accordance with field data received from the geologists of the Tropical Oil Company who were at the time engaged in a detailed study of the Guaduas area, east of the towns of Honda and Ambalema on the Upper Magdalena River, Colombia. The age of the Guaduas formation, which is widely distributed in this part of the country, also outside the area under investigation, was given in my publication as: Upper Cretaceous or in part Tertiary, and the name of Guaduas limestone was proposed for the reef-like limestone lenses from which the fossiliferous samples were collected. Subsequent field work has, however, led to the conclusion that the limestone should not be included in the Guaduas. I have to thank Mr. W. M. Chappell of the Texas Petroleum Company for pointing out to me that the question is of sufficient general interest to justify a corrective note.

The name "Guaduas Beds" was introduced by Hettner (1892, p. 29) for a system of alternating red sandstones and red to violet shales which form the crest of the second

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mountain ridge (Cordillera del Sargento) east of the Magdalena in the Honda district and the synclinal valley of Guaduas east of that ridge. In the lower part of the west slope of the Cordillera del Sargento occur the outcrops of the conglomerate and limestone lenses described in my previous paper. As the Guaduas formation also contains several conglomeratic beds in the area, this conglomerate was at first also included in it. However, whereas the Guaduas formation is essentially non-marine, this conglomerate is clearly of marine origin and belongs, therefore, to a different cycle of sedimentation.

Hettner's description of the area presents too few details to give a clear picture of the local situation. Washburne and White (1923), in their discussion of the same area, do not describe the marine conglomerate in their text either, but in the "Correlated stratigraphic sections of Colombia" (their fig. 2) they insert between the bituminous shale and limestone series, considered as of Middle Cretaceous age, and their "coal-bearing formation," which should be interpreted as Hettner's Guaduas, a complex of 400′ of coarse-grained sandstones, millstone grits and limestone conglomerates which they call the Cemaroma formation (mis-spelled for: Cimarrona formation; see below). They apparently did not have paleontological evidence for its age and placed the Cretaceous-Tertiary boundary at the base of it.

The Tropical Oil geologists (H. F. Belding and L. Mazurczak, private company report) distinguish the uppermost part of the Cretaceous shale series in the area as a separate formation, for which they use the name of Umir formation (after the time-equivalent Umir of the Sogamoso area; see Wheeler 1935). The Umir was considered to be of Eocene age at the time but has since been recognized as Cretaceous (Maestrichtian) on micro-foraminiferal evidence (*Siphogenerinoides bramletti* fauna). Only the top of it is exposed near Honda and it is overlain in this area by the Cimarrona formation, which is described as a series 140 meters thick of fine and coarse conglomerates, hard gray and brown sandstones, sandy siltstones and claystones, best exposed in the road cuts along the Honda-Guaduas highway on the N. side of Quebrada La Cimarrona. The topmost bed of this formation is a conglomerate containing the foraminiferal limestone reefs which were determined as Maestrichtian. For this limestone the new name of Cimarrona limestone is proposed here to replace the erroneous name of Guaduas limestone. The reefs, which vary in thickness from two to ten meters, occur in a trend of more than 25 kilometers along the upthrust east side of the fault that runs east of the Magdalena River in this area.

As the Umir in the Honda district is already of Maestrichtian age, the Cimarrona must represent a fairly high horizon of the Maestrichtian, corresponding with the top of the Guadalupe formation (Hettner). It is described as a separate formation because the horizon has, up to now, never been found in a similar reef facies development anywhere else in the country. The overlying Guaduas formation may, in the opinion of the Texas Oil geologists, include some (post-Maestrichtian?) Cretaceous, but by far the greater part of it is definitely of Tertiary age.

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NOMENCLATURAL NOTES

FENESTELLA DEISSI (NEW NAME) FROM THE MIDDLE DEVONIAN OF MICHIGAN, AND RELATED FORMS

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ABSTRACT—Because the name of the Middle Devonian form *Fenestella foraminosa* Deiss is preoccupied it is renamed *F. deissi* Elias. The form is closely related to *F. serratula* Ulrich of Upper Mississippian and Lower Pennsylvanian age and is its apparent ancestor. The species from the Lower Carboniferous of Kuznetsk Basin described as *Fenestella tenax* "var." (Ulrich, 1890) by Nekhoroshev (1926) is a form transitional between *F. deissi* Elias and *F. serratula* Ulrich, and is designated *F. serratula* var. *nekhoroshevi* Elias; it probably belongs to the lower or lowermost Tournaisian.

Introduction.—When comparing some Carboniferous Bryozoa with related forms from the Devonian I noticed that Deiss, who described in 1932 the Fenestellidae from the Middle Devonian of Michigan, named one of his new species *F. foraminosa*, a name preoccupied by Eichwald (1860, p. 363, pl. 23, figs. 7a, 7b) for a Russian late Paleozoic *Fenestella*.

I have called attention of Dr. Charles F. Deiss to this fact, and he cordially suggested that because "many years have passed since I worked on Bryozoa, and as my time now and during the past three years has been consumed with administration . . . would not have the time to do the job carefully," and so "if you wish to rename the species or publish a comment about it in the Journal of Paleontology, you do so with my sincere appreciation" (written communication of Oct. 11, 1948). Following this suggestion I have taken over the job of comparative investigation and renaming of the species in question.

First of all I have made it certain that the form from Michigan is not, by a chance of coincidence, the same as or closely related to *Fenestella foraminosa* Eichwald. Fortunately the latter has been repeatedly described by Russian paleontologists, and its type was revised by Nikiforova (1938, pp. 73–75, 229–230). It is clearly quite different from the species named so by Deiss: *F. foraminosa* Eichwald has much coarser meshwork, with 3 to 4 zooecia per fenestrule, while the form from Michigan has nearly two times finer meshwork with two zooecia per fenestrule.

American species.—Further investigation proved that the form from Michigan is closest to one of the commonest American species *Fenestella serratula* Ulrich from the Upper Mississippian and Lower Pennsylvanian of the Midwest. The lowest known occurrence of the latter is from the Warsaw and Keokuk beds of Illinois, from where it was originally described by Ulrich (1890, pp. 544–545, pl. 50, figs. 5–5c); it was subsequently revised on topotypes from the Warsaw by Condra and Elias (1944, pp. 72–76, pl. 13, figs. 6–8). The standardized meshwork formula for *F. serratula* (where the figures indicate number of branches per 10 mm., fenestrules per 10 mm., zooecia per 5 mm., and carinal nodes per 5 mm.) is 22–30/17–24//25–28/20–28 (Condra and Elias, 1944, table 2 on p. 73). From the measurements by Deiss his species has 24 dissepiments in 10 mm., which indicates about as many (24) fenestrules per 10 mm., and its apertures number "twenty-five in 5 mm., occasionally twenty-seven in 5 mm." (Deiss, 1932, p. 245); clearly, his figures are practically the same as those for *F. serratula* from the Warsaw. Further similarity can be seen in the features as follows. Branches are spaced similarly, about 25–30 branches per 10 mm. as can be counted on Deiss' pl. 3, fig. 3. Dissepiments are slightly depressed on reverse. Outline of the zooecial chamber is pentagonal, as seen on Deiss' pl. 3, fig. 4,

and Condra and Elias' pl. 13, figures 7, 8. Ulrich originally noted the presence of "comparatively strong median carina, carrying small nodes, which give it on a side view the serrated appearance that has suggested the name," (1890, p. 544); and Deiss likewise describes for his form a carina "minutely nodose on summit" (1932, p. 245). Thus there is sufficient evidence for placement of the form from Michigan close to *F. serratula* from the Upper Mississippian of Illinois. However, there is considerable difference in the age of the two forms, and, as might have been expected, there are indeed some differences in their structure that are as follows.

According to the description by Deiss the branches of his form are adorned on the reverse "with a large node near junction of dissepiments" (p. 245). Ulrich does not mention nodes of any kind on the reverse of *F. serratula* from any stratigraphic occurrences of this form, nor have Condra and Elias observed any on the specimens which they describe. On the other hand Ulrich mentions on reverse of the branches "an occasional long, barbed, spine-like appendage" (1890, p. 544). Such appendages have been also occasionally observed on this species by Condra and Elias. However they are not mentioned in their description, as they have been found also occasionally on a number of other species of *Fenestella*, and hence they are not considered by them of taxonomic significance. These appendages are quite sporadic in development, have no relationship to the ordinary nodes, and therefore the presence of the latter on the reverse of the branches, as noted by Deiss, seem to differentiate it taxonomically from the Carboniferous form *F. serratula*. Furthermore, thanks to the excellent photograph of a tangential section of the Devonian form (Deiss, 1932, pl. 3, fig. 4) it can be seen that the outline of its zooecial chamber though generally pentagonal, as in *F. serratula*, differs from the latter by having its outer side convex outwardly, instead of quite straight, as in *F. serratula* (see Condra and Elias, 1944, pl. 13, figs. 7, 8). Finally, Deiss notes that the peristomes in his form are "very strongly developed, indenting borders of fenestrules" (1932, p. 245). This is not the case, however, in *F. serratula* from the Mississippian, as illustrated by Ulrich (1890, pl. 50, figs. 5–5c) or by Condra and Elias (1944, pl. 13, figs. 6–8; pl. 21, figs. 4, 5). Only in a much later representative of *F. serratula* from the Oquirrh formation of Utah (correlated with the upper Des Moines) the apertures project slightly into the fenestrules (Condra and Elias, 1944, pl. 36, fig. 3), but in this advanced form the fenestrules are proportionally longer than the fenestrules in the Mississippian representatives of *F. serratula*, or in the discussed form from Michigan.

Taking all this into account it seems justifiable to consider the form from Michigan a species distinct from *F. serratula*, though undoubtedly closely related to it and apparently its direct ancestor. It is fitting to rename it in honor of the author of the "Description and Stratigraphic correlation of the Fenestellidae from the Devonian of Michigan," the distinct merit of which is a consistent sectioning of all species of *Fenestellidae*, at the time when most American paleontologists studied only their external features. Thus *Fenestella foraminosa* Deiss becomes *Fenestella deissi* Elias; the holotype remains as designated by Deiss (1932, p. 245) No. 10498 Univ. of Michigan. Paratypes Nos. 10519, 10520, 10521, and 10522, U. M.; horizon and locality—"Gray limestone of Location 36," Traverse group of Michigan, correlated with the Middle Devonian.

Related Russian forms.—A form that appears transitional between *F. deissi* and *F. serratula*, and comes from the lower part of the lower Carboniferous of Kuznetsk Basin, western Siberia, is described by Nekhoroshev as *F. tenax*. Nekhoroshev says that although his form is very close to *F. serratula* Ulrich its dimensions are identical with those of the "variety of *F. tenax* Ulrich from the Chester of Illinois," which is indeed correct; however, Condra and Elias (1944, p. 72) refer Ulrich's *F. tenax* "variety from the Chester group" (1890, pp. 546–547, pl. 51, fig. 2e only) to *F. serratula*, as it is nearer to the latter species in its dimensions. However, the dimensions of Nekhoroshev's form, which are 26–28 (to 30)/22–25//24–26, are still closer to those of *F. deissi*, and the Siberian form has also two additional characters common with the latter, and

which distinguish both from *F. serratula:* presence of "nodes on the reverse of the branches, particularly at the junctions of branches and dissepiments" (Nekhoroshev, 1926, p. 1249), and the shape of fenestrules which "are indented by the projecting appertures of the zooecia" (ibid., p. 1248). On the other hand the outline of zooecial chamber shown on the drawing figure 2, pl. 20 (Nekhoroshev, 1926) is like that in *F. serratula* rather than *F. deissi,* as its long lateral side is perfectly straight. Although Nekhoroshev tends to correlate the bryozoan faunule from Kuznetzk Basin, which he describes, with that from the Keokuk-Warsaw of America (1926, p. 1279), later stratigraphic and paleontologic investigations record the presence of the same type of bryozoan faunule in those limestones of the same Kuznetzk Basin, which are now correlated with Etroeungt or lowermost Carboniferous of Europe. Also the same faunule appears in the next higher limestones which are now being correlated with the middle and upper Tournaisian of Europe (Rotai, 1938). Hence it seems quite possible that the form described by Nekhoroshev belongs to earliest Mississippian age, and therefore is transitional between *F. deissi* and *F. serratula* in time of its occurrence, which would fit well with the transitional nature of its structure. It may be designated as *F. serratula* var. ***nekhoroshevi,*** n. var.; its type being the specimen illustrated by Nekhoroshev, 1926, on pl. 19, figure 1, and paratype slide No. 17 illustrated on his pl. 20, figure 1; its differences from *F. deissi* and *F. serratula* have been noted above.

It may be added, *en passant,* that the form described from the same beds and area by Nekhoroshev (1926, pp. 1247–1248) as *Fenestella serratula* is in all respects more nearly like *F. cumingsi* Condra and Elias (1944, pp. 103–104; pl. 10, fig. 46; pl. 21, fig. 6), a form unknown at the time when Nekhoroshev described his faunule.

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VACUOCYATHUS A NEW NAME FOR *COELOCYATHUS* VOLOGDIN, 1933

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The name *Vacuocyathus* is proposed to take the place of *Coelocyathus* Vologdin, which is preoccupied by *Coelocyathus* Schluter, 1886 and by *Coelocyathus* Sars, 1857 (Nyt. Mag. Naturv., 9, (2), 126). Vologdin apparently proposed the name in 1933 in an unpublished manuscript; used the name in 1934 (Comptes Rendus de l'Academie des Sciences de l'URSS, vol. 4, pp. 499–505, fig. 4.) without giving a formal definition; used it again in 1937 (Pal. Lab. of Moscow State University, Problems of Palaeontology, vol. 2 and 3, p. 472, pl. 4, fig. 6), and finally formally defined it and gave descriptions of two species in 1939 (Pal. Lab. of Moscow State University, Problems of Paleontology, vol. 5, Middle Cambrian Archaeocyatha and Algae from the south Urals, p. 237–238, figs. 11a, b, and c.). *Coelocyathus kidrjassovensis* Vologdin, 1939 was designated as the genotype, and becomes the genotype of *Vacuocyathus.*

Simon, 1939 (Abh. senckenberg, naturf. Ges, vol. 448, pp. 25–26) pointed out the

invalidity of the name *Coelocyathus*, but did not correct the error. He furthermore doubted the validity of Vologdin's description, that the organism: "consists only of two porous concentric walls" as being mechanically impossible. While it is possible that Vologdin's material was in a poor state of preservation, so that no intervallum structures were preserved, I would like to point out that it is quite possible for a sponge to have some of its skeletal elements supported solely by its living tissue. Furthermore by 1940 Vologdin had similar forms described from more than one locality. It is regrettable that the impossibility of communication with USSR makes it impracticable for me to ask Dr. Vologdin to correct the nomenclatural error himself and to refute Simon's statement.

NOMENCLATURAL NOTES ON PLEOSPONGE GENERA *ARCHAEOCYATHUS, SPIROCYATHUS, FLINDERSICYATHUS PYCNOIDOCYATHUS* AND *CAMBROCYATHUS*

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The proposed changes in nomenclature of Pleosponges involve one of the earliest known species of the class—*Cambrocyathus* (*Archaeocyathus*) *profundus* Billings. Considerable disagreement and confusion resulted in the past from incomplete or erroneous interpretation of which of the early species of Billings was to be regarded as the genotype of *Archaeocyathus*. Billings in 1861 described two species of *Archaeocyathus—A. atlanticus* and *A. minganensis*. In 1865 he revised his original description and erected a new species, *A. profundus*. Realizing that *A. profundus* represents the outstanding characteristics of this newly discovered group of organisms better than *A. atlanticus*, in 1865 he apparently considered *A. profundus* the genotype, thus disregarding his own definition of the genus as published in 1861, based on *A. atlanticus*. According to rules of nomenclature, however, choice of genotype is limited to originally described species—that is to *A. atlanticus* and *A. minganensis*. Of these *A. atlanticus* is the only possible choice because it was first mentioned, and because *A. minganensis* was later shown by Hinde (1889) to be a true spicular sponge and removed from the Pleosponges altogether. *Archaeocyathus atlanticus* Billings, 1861, is therefore the only species available for the type of *Archaeocyathus*. The holotype (No. 369, Geological Survey, Ottawa, Canada) was illustrated by Okulitch, 1940, pl. 1, figs. 1, 2.

Archaeocyathus is the type genus of family Archaeocyathidae Okulitch, (not Taylor, not Vologdin). Unfortunately Hinde (1889) in his revision of Pleosponges took *A. profundus* to be the genotype. Since *A. atlanticus* is obviously not cogeneric with *A. profundus* he proposed the new name *Spirocyathus* for *A. atlanticus*. *Spirocyathus* is therefore an exact synonym of *Archaeocyathus* and obviously invalid. It follows that the family name Spirocyathidae used by Taylor, Bedford in his earlier papers, and Vologdin throughout his work is also invalid as according to Article 5 of the rules of nomenclature, "The name of a family or subfamily is to be changed when the name of its type genus is changed." Bedford, (1937, p. 28) proposed a new name, *Flindersicyathus*, to take the place of *Spirocyathus*. Since *Spirocyathus* is a synonym of *Archaeocyathus*, *Flindersicyathus* (Flindersicyathidae) is also a synonym of *Archaeocyathus*, and therefore invalid.

Family Archaeocyathidae therefore is based on *Archaeocyathus atlanticus* Billings, 1861, as the genotype and includes the following genera: (names in parentheses signify synonyms or probable synonyms)

Archaeocyathus, Billings, 1861
(=*Spirocyathus*, Hinde, 1889)
(=*Retecyathus*, Vologdin, 1932)
(=*Flindersicyathus*, Bedford, 1937)
Araneocyathus, Vologdin, 1937
Archaeopharetra, Bedford, 1936
Copleicyathus, Bedford, 1937

Metaldetes, Taylor, 1910
(= *Metacyathus*, Bedford, 1934)
Protopharetra, Bornemann, 1884

Since *Archaeocyathus profundus* Billings, 1865, is generically distinct from *Archaeocyathus atlanticus* Billings, a new name is required for it. Okulitch, in 1937 and 1940 proposed the name *Cambrocyathus*, designating *Archaeocyathus profundus* as the genotype. The genus is based on specimens No. 341, 341 a, 373 m in the collection of the Geological Survey of Canada labelled cotypes, and specimens Nos. 373, 373 a, d, e, and f, labelled plesiotypes. Specimen No. 341 was chosen by Okulitch, 1940, p. 81 as the genolectotype, and was illustrated (1940) on pl. 2, figs. 1 and 2.

Cambrocyathus was made the type genus for family Cambrocyathidae (Okulitch, 1943, pp. 53 and 72). Okulitch (1940 and 1943) realized that *Cambrocyathus* is close to the Australian genus *Pycnoidocyathus*, Taylor, 1910, but in the absence of authentic comparative material regarded the two genera as possibly distinct.

Since then, however, because of extensive study of specimens of *Cambrocyathus* from several localities in North America and examination of Australian specimens of *Pycnoidocyathus*, as well as a very close study of the literature, the writer feels that he is unable to differentiate between *Cambrocyathus* and *Pycnoidocyathus* above specific rank.

Since *Pycnoidocyathus* has priority (Taylor, 1910, p. 131, Pl. 12, figs. 68, 69, 70 and 71) *Cambrocyathus* is a virtual synonym of *Pycnoidocyathus*. The genotype of *Pycnoidocyathus* is *P. synapticulosus*, Taylor, 1910 (p. 132, pl. 12, fig. 69), by subsequent designation by Bedford (1939, p. 78) and by Simon (1939, p. 35). The writer is in full agreement with this choice. Accordingly *Pycnoidocyathus* becomes type genus of new family Pycnoidocyathidae, this family being essentially equivalent to Cambrocyathidae, Okulitch 1943, and therefore replacing it.

Simon (1939, pp. 35, 36) erroneously regarded *Pycnoidocyathus* as a subgenus of *Ethmophyllum*. *Ethmophyllum* differs radically from the Pycnoidocyathidae in having the inner wall of a different type altogether, and lacking synapticulae and dissepiments. *Ethmophyllum* is placed by Okulitch, Vologdin, and Bedford not only in a distinct family, but by Okulitch and Bedford as a member of a distinct order.

It is regrettable that *Pycnoidocyathus* (*Archaeocyathus*) *profundus* (Billings), one of the oldest known species of Pleospongea, is thus deprived of its position as the type species of a genus and family, but this is unavoidable under the rules of priority.

The genus *Pycnoidocyathus* now contains the following species:

P. amourensis (Okulitch) 1943
P. ceratodictyoides (Raymond) 1931
P. columbianus (Okulitch) 1943
P. dissepimentalis (Okulitch) 1943
P. donaldi (Okulitch) 1948
P. loupensis (Okulitch) 1940
P. maximipora Bedford 1936
P. occidentalis (Okulitch) 1943
P. parvulus Bedford, 1936
P. profundus (Billings) 1861
P. ptychophragma Taylor 1910
P. simplex Taylor 1910
P. synapticulosus Taylor 1910 (genotype)
P. vicinisepta Bedford 1936

Pycnoidocyathus has the following characteristics: cups of cylindrical or conical shape, the outer wall transversely annulated by deep horizontal bulges. Parieties in part well defined and radial, in part wavy, passing into trabecular tissue within the bulges. All parieties more or less synapticulate. Dissepiments are present in some of the species. Inner wall simple, perforated by the usual pores or larger canals.

A closely related genus is *Archaeofungia*, Taylor, 1910, which differs from *Pycnoidocyathus* in that its outer wall lacks the annulations.

The family Pycnoidocyathidae contains the following genera:

Archaeofungia Taylor, 1910
(= *Metafungia* Bedford, 1934)
Ardrossocyathus Bedford, 1937
Loculicyathus Vologdin, 1931
Metethmophyllum Okulitch, 1943
Paranacyathus Bedford, 1937
(= *Paracyathus*, Bedford, 1936)
(= *Spirocyathella*, Vologdin, 1940)
Pycnoidocyathus Taylor, 1910
(= *Cambrocyathus*) Okulitch, 1937
Sibirecyathus, Vologdin, 1937

Sibirecyathus Vologdin is possibly a synonym of *Archaeofungia* Taylor.

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NEW NAME FOR *FAVOSITES PROXIMUS* DAVIS

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Favosites proximus Davis (Kentucky Fossil Corals, plate 15, figs. 4–6; plate 28, fig. 3, 1887) is a homonym of *F. proximus* Hall (Rept. New York State Geol. for 1882, expl. plate 7, figs. 13–15, 1883). In order to avoid repeating this homonymous name in the forthcoming instalment of the Catalogue of North American Devonian Fossils. *F. proximus* Davis is here renamed *F. proximatus.*

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JOSEPH FRANK RICCIO, Univ. Southern California, B.A., '50; Geol. Dept. Univ. Southern California, Los Angeles 7, Calif. Cambrian trilobites; Tertiary forams. Publ. 5 pp. *The Compass*, 1949, W. H. Easton, Robert S. Stevenson.

HUGH DRESSER, Univ. Cincinnati, B.S., '50; Grad. Asst., Univ. Cincinnati, Cincinnati 20, Ohio. Invertebrate paleontology and stratigraphy. K. E. Caster, W. H. Shideler.

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ERRATUM

In: Otto Haas, Ammonites: Tetrabranchiata or Dibranchiata? Journal of Paleontology, vol. 24, no. 1, pp. 109–110, January, 1950, replace, on p. 110, 2d and 3d line, "Dibranchiata" by "Tetrabranchiata."

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